NetLogo 4.0 User Manual

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What is NetLogo?

NetLogo is a programmable modeling environment for simulating natural and social phenomena. It was authored by Uri Wilensky in 1999 and is in continuous development at the Center for Connected Learning and Computer−Based Modeling.

NetLogo is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of "agents" all operating independently. This makes it possible to explore the connection between the micro−level behavior of individuals and the macro−level patterns that emerge from the interaction of many individuals.

NetLogo lets students open simulations and "play" with them, exploring their behavior under various conditions. It is also an authoring environment which enables students, teachers and curriculum developers to create their own models. NetLogo is simple enough that students and teachers can easily run simulations or even build their own. And, it is advanced enough to serve as a powerful tool for researchers in many fields.

NetLogo has extensive documentation and tutorials. It also comes with a Models Library, which is a large collection of pre−written simulations that can be used and modified. These simulations address many content areas in the natural and social sciences, including biology and medicine, physics and chemistry, mathematics and computer science, and economics and social psychology. Several model−based inquiry curricula using NetLogo are currently under development.

NetLogo can also power a classroom participatory−simulation tool called HubNet. Through the use of networked computers or handheld devices such as Texas Instruments graphing calculators, each student can control an agent in a simulation. Follow this link for more information.

NetLogo is the next generation of the series of multi−agent modeling languages that started with StarLogo. It builds off the functionality of our product StarLogoT and adds significant new features and a redesigned language and user interface. NetLogo is written in Java so it can run on all major platforms (Mac, Windows, Linux, et al). It is run as a standalone application. Models can be run as Java applets inside a web browser.

Features

You can use the list below to help familiarize yourself with the features NetLogo has to offer.

- System:
    - ♦ Cross−platform: runs on Mac, Windows, Linux, et al
- Language:
    - ♦ Fully programmable
    - ♦ Simple language structure
    - ♦ Language is Logo dialect extended to support agents
    - ♦ Mobile agents (turtles) move over a grid of stationary agents (patches)
    - ♦ Create links between turtles to make aggregates, networks, and graphs
    - ♦ Large vocabulary of built−in language primitives
    - ♦ Double precision floating point math (IEEE 754)
    - ♦ Runs are exactly reproducible cross−platform
- Environment:

- View your model in either 2D and 3D
- Scalable and rotatable vector shapes
- Turtle and patch labels
- Command center for on−the−fly interaction
- Interface builder w/ buttons, sliders, switches, choosers, monitors, text boxes, notes, output area
- Speed slider lets you fast forward your model or see it in slow motion
- Powerful and flexible plotting system
- Info tab for annotating your model
- HubNet: participatory simulations using networked devices
- Agent monitors for inspecting and controlling agents
- Export and import functions (export data, save and restore state of model, make a movie)
- BehaviorSpace tool used to collect data from multiple runs of a model
- System Dynamics Modeler

- Web:
  - Models can be saved as applets to be embedded in web pages (note: some features are not available from applets, such as some extensions and the 3D view)

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To reference this software in academic publications, please use: Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer−Based Modeling, Northwestern University, Evanston, IL.

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MersenneTwisterFast

For random number generation, NetLogo uses the MersenneTwisterFast class by Sean Luke. The copyright for that code is as follows:

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MovieEncoder

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What's New?

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you. Please send comments, suggestions, and questions to feedback@ccl.northwestern.edu, and bug reports to bugs@ccl.northwestern.edu.

Version 4.0 (September 2007)

- models:
  - new earth science models: Continental Divide, Climate Change
  - new chemistry model: Diprotic Acid
  - new materials science model: Solid Diffusion
  - new mathematics models: PANDA BEAR Solo, Surface Walking 2D
  - new network model: Team Assembly
  - new computer science models: Hex Cell Aggregation, Particle System Basic, Particle System Fountain, Particle System Waterfall, Particle System Flame
  - new game: Planarity
  - new social science models: Language Change, El Farol (old El Farol model is now named El Farol Network Congestion)
  - new NIELS electromagnetism models: Ohm's Law, Series Circuit, Parallel Circuit
  - new Urban Suite curricular models
  - new suite of Connected Chemistry curricular models
  - new suite of BEAGLE Evolution curricular models
  - models improved and promoted to verified: Dice Stalagmite, Autumn, Conic Sections 2, Echo, Rebellion, Daisyworld, Sound Machines, Birthdays, Bug Hunt Speeds, Electrostatics
  - other improved models: Small Worlds (bugfix), most CA 1D models (bugfix), Star Fractal (overhauled code), Genetic Drift T Interact (added optional walls), Flocking (smoother animation), Planarity (simpler code), Mimicry (simpler code), GasLab Circular Particles (cleaner code, added plots), acid/base models (simpler code)
  - new Code Examples: Random Grid Walk Example, Link Lattice Example, Lattice−Walking Turtles Example, Link−Walking Turtles Example, Intersecting Links Example, State Machine Example, Breed Procedures Example, Link Breeds Example, Mouse Drag Multiple Example, Hill Climbing Example, Rolling Plot Example, Ask−Concurrent Example, Ask Ordering Example, Random Network Example, Fully Connected Network Example, Mobile Aggregation Example, Wall Following Example, Circular Path Example, Profiler Example
  - improved Code Examples: Halo Example (simplified using `tie`), Intersecting Lines Example (bugfix), RGB and HSB Example (now demonstrates RGB lists), File Output Example
  - new HubNet activity: PANDA BEAR
  - new HubNet code example: Template
  - improved HubNet activities: Dice Stalagmite HubNet (now verified), Bug Hunters Camouflage (now verified), Root Beer Game (now verified), Disease Doctors (now verified), Minority Game
- documentation:
  - new Transition Guide section in User Manual provides guidance on making models from previous versions work in NetLogo 4.0
  - new Syntax section in Programming Guide section of User Manual

- ♦ new Applets section in User Manual

- features:
  - ♦ most models now run somewhat faster:
    - ◊ while results vary from model to model, typical speedup is around 1.5x
    - ◊ the speedup comes from an improved compiler that now partially compiles NetLogo code into Java byte code
  - ♦ links are now their own type of agent, alongside turtles and patches; this is useful for network models, geometry models, and much else
  - ♦ new Link Shapes Editor lets you control the appearance of links
  - ♦ logging allows researchers to record students' actions for later analysis
  - ♦ built in tick counter for keeping track of model time (see language changes, below)
  - ♦ new view update system:
    - ◊ there are now two view update modes, tick−based and continuous
    - ◊ continuous is the default when you start up NetLogo; tick−based is the default for most models in the Models Library; continuous update mode is useful for non−tick based models like Termites, but may also be useful during debugging
    - ◊ tick−based updates are faster for most models and avoid displaying intermediate state
    - ◊ buttons no longer have a "force view update" checkbox; most models should use `tick` and/or `display` instead
  - ♦ improved speed slider:
    - ◊ you can now use the slider to "fast forward" a model (by updating the view less often)
    - ◊ in tick−based update mode, going slower pauses between ticks rather than showing intermediate states
    - ◊ in continuous update mode, going slower shows intermediate states; you can even go so slow you can watch agents move one at a time
  - ♦ new input boxes in Interface tab permit entering text, numbers, colors, or NetLogo code as model parameters
  - ♦ arrays and hash tables are now supported via extensions (see Arrays & Tables section of User Manual)
  - ♦ new profiler extension lets you measure the running times of your procedures
  - ♦ new experimental `__includes` keyword allows splitting model code into multiple files
  - ♦ color variables can now contain either a NetLogo color or an RGB color (as a list of three numbers)
  - ♦ programmable slider bounds (you can now use any NetLogo reporter as the min, max, or increment of a slider)
  - ♦ exporting the world now includes all plot data, and when you import a world the contents of plots are restored
  - ♦ the sound extension can now play audio files in addition to MIDI sounds
  - ♦ notes, monitors and output areas now have editable font size
  - ♦ the color of text in notes is now editable, and a note's background may now optionally be transparent
  - ♦ "Snap to Grid" in Interface tab
  - ♦ added menu items (and F1 keyboard shortcut) for quickly accessing NetLogo Dictionary
  - ♦ sliders may now be vertical or horizontal
  - ♦ model files with unsaved changes are auto−saved to a temporary files directory, in case of freezes/crashes

- HubNet clients are much easier to edit now (the client is no longer a separate model)
- Mathematica−NetLogo link provides a real−time link between Mathematica and NetLogo, for controlling model runs and visualizing and analyzing results after the fact or in real time

- language changes:
  - the `ask` command now always runs "without interruption"; if you need the old−style concurrent behavior, use `ask−concurrent`
  - the syntax for using extensions is now simpler (no underscores, no double quotes, no .jar suffix)
  - new tick counter primitives: `tick`, `ticks`, `tick−advance`, `reset−ticks`
  - changes to how numbers work in NetLogo:
    - all numbers are now double precision floating point
    - numbers with no fractional part print as integers (without the decimal point)
    - much larger integers can now be represented (up to about 9x10^15)
  - new primitive `of` replaces `VARIABLE−of`, `value−from`, `values−from`
  - new reporter `all?` tests whether all agents in an agentset satisfy a condition
  - turtle who numbers are now never reused until `clear−turtles` or `clear−all`
  - new primitive `other` reports an agentset excluding the calling agent (this is short for `with [self != myself]`)
  - removed `other−turtles−here` and `other−<breeds>−here` from language; use `other` instead
  - new `move−to` command moves a turtle to the location of the specified turtle or patch
  - for commands that create turtles or links, the commands following are now optional
  - `create−custom−turtles` and `create−custom−<breeds>` no longer exist; instead, use `create−turtles` and `create−<breeds>` which now take an optional command block
  - `create−turtles` now makes turtles with random headings and colors; to get evenly spaced turtles with sequential colors and id numbers use `create−ordered−turtles` (`cro` for short)
  - new `turtle−set`, `patch−set`, and `link−set` reporters let you build agentsets in a variety of ways
  - removed `turtles−from` and `patches−from` from language (use `turtle−set` and `patch−set` instead)
  - new `uphill`, `uphill4`, `downhill`, and `downhill4` commands for doing hill−climbing
    - these new commands replace the old reporters with the same names
    - the new commands have somewhat different semantics that are less prone to problems
    - models using the old reporters will require hand changes
  - new reporters `no−turtles`, `no−patches`, and `no−links` report empty agentsets
  - two agentsets can now be tested for equality
  - the `tie` and `untie` commands are no longer experimental; they now take no inputs and can only be used by links; two tie modes are available, "fixed" and "free"
  - the + operator only adds numbers now; it doesn't work on strings or lists anymore; models must be changed by hand to use `word` instead for strings and `sentence` instead for numbers
  - new `histogram` command replaces old `histogram−list`, `histogram−from` commands
  - removed `random−int−or−float` from the language; some models may need to be changed by hand to use `random` or `random−float` instead

- removed `nsum` and `nsum4` from language; use `sum [reporter] of neighbors/neighbors4` instead
- new agentset primitives `min-n-of` and `max-n-of`
- new primitive `with-local-randomness` runs code without altering the state of the random number generator
- new file I/O primitive `file-flush` forces output to disk
- new color primitive `base-colors` reports a list of the 14 basic NetLogo hues
- the `turtle` primitive no longer accepts non-integer inputs
- the `patch` primitive now accepts non-integers and rounds them, and also wraps if allowed
- the observer may no longer use `patch-at`, `turtles-at`, and `BREED-at`; use `patch`, `turtles-on patch`, and `BREED-on patch` instead
- comparison operators now work on turtles, patches, and links
- new primitive reporter `plot-pen-exists?`
- old `rgb` and `hsb` primitives renamed to `approximate-rgb` and `approximate-hsb`; they now expect inputs in 0-255 range instead of 0-1.0
- the `hsb` and `rgb` reporters now report RGB lists instead of NetLogo colors
- new primitive `import-pcolors-rgb` imports images into the patches as RGB colors
- new reporter `netlogo-applet?` lets you test whether the model is running as an applet or not
- code may now set a slider to values which violate the minimum, maximum, or increment
- `locals` no longer exists; use `let` instead
- extension primitives must now (by default) be referred to using the extension name, e.g. `sound:drums` instead of just `drums`
- the `file-read` primitive now skips over comments
- got rid of many undocumented alternate names for primitives

- user interface changes:
  - "note" is the new name for the widget formerly known as "text box"
  - sliders may now be moved using the mouse scroll wheel
  - built-in variables are now syntax-colored the same purple as primitive reporters
  - dialogs associated with the `user-*` primitives have more consistent appearance and functionality
  - contextual menus added to text areas (for cut/copy/paste and dictionary lookup)
  - Pens button removed from plots (you now edit the plot to show or hide the pens legend)
- engine fixes:
  - monitors now use an auxiliary random generator, so code in monitors won't affect model run reproducibility
  - the `run` and `runresult` primitives are now drastically faster when called repeatedly on the same string
  - the `display` command now works even when used by a turtle, patch, or link
  - internally, lists are now linked lists, not arrays; this does not affect the behavior of models, but may affect performance (positively or negatively, depending on what list operations you are doing; see Programming Guide)
  - when turtles move in a way that does not indicate direction (e.g. `setxy`), the shortest path is now always drawn (even if it wraps)
  - fixed bug where in some conditions, exporting and then re-importing the world during a model run could alter the outcome (by affecting how who numbers were reused)

    - the `sort-by` primitive is now stable (that is, it does not disturb the existing order of equal items)
    - the `file-read` primitive is now much faster at reading very long lists
    - fixed bugs where `in-cone` and `distance` didn't work properly in some topologies
    - fixed bug where some layout commands were not controlled by the random seed
    - the global variables associated with sliders, switches, choices, and input boxes now behave the same when running headless as in the GUI, that is, they reject values that are of the wrong type or out of range
- other fixes:
    - the Halt item on the Tools menu now works in more situations (rather than hanging NetLogo)
    - if endless recursion occurs, NetLogo now reports the error instead of bombing
    - while startup commands run, the user is now prevented from interacting with the model
    - plotting is now supported when running headless (use `export-plot` or `export-world` to save plotted data for later perusal)
    - in the 3D view, turtle shapes now wrap around the edges if the world has wrapping enabled
    - upgraded JOGL, fixing 3D view bugs for some users
    - applets can now find files associated with the model even if the model file is in a different location than the HTML file
    - in the system dynamics modeler, rate connectors can now be repositioned
    - the system dynamics modeler now shows the location of syntax errors
    - in the system dynamics modeler, you can now control which plot is used using `set-current-plot`, and which stocks are plotted is controlled by `plot-pen-exists?`
    - default maximum Java heap size raised to one gigabyte
    - headless mode now works with IBM's Java
    - the GoGo extension is now easier to use (no separate installation steps required)
    - new checkbox allows you to turn off the world wire frame in the 3D view
- extensions API changes:
    - the extensions API now has a version number, so extensions can be used with different NetLogo versions as long as the API version number hasn't changed
    - instead of being just a jar, an extension is now a directory containing a jar, so that the directory can contain other supporting files
    - there is now rudimentary support in the API for extensions to define new data types (the array and table extensions are examples)
    - the random number generator is now accessible by extensions
    - sample extensions are now installed with Java source code included (formerly it was separate downloads)

Version 3.1.4 (February 2007)

- installer supports Windows Vista
- rewritten and expanded Tutorial #3
- new sound extension command `play-note-later` for playing musical phrases
- extensions not requiring additional jars work in saved applets
- bugfixes

Version 3.1 (April 2006)

- topologies (wrapping at world edges now optional)
- automatically randomized ordering of agentsets
- you now specify the singular form of a breed name as well as the plural
- `sort` and `sort-by` work on agentsets now
- link primitives for network and geometry models (experimental)
- `__tie` and `__untie` primitives (experimental)

Version 3.0 (September 2005)

- 3D view (for 2D models)
- System Dynamics Modeler
- `follow`, `ride` and `watch` commands for tracking particular agents
- "drawing layer" for marks left by turtles
- more attractive colors
- more attractive Information tab
- GoGo extension for interfacing NetLogo with physical devices
- Color Swatches dialog helps you choose colors
- image file importing
- buttons take turns now (instead of interleaving their code with each other)

Version 2.1 (December 2004)

- "headless" mode for command line operation
- editor highlights matching parentheses and brackets
- "action keys" let buttons be triggered by keypresses
- makes QuickTime movies of models
- add "output area" to models
- improved shapes editor and built-in shapes
- new primitives including `let` and `carefully`
- computer HubNet:
    - now more reliable
    - clients automatically find server
    - improved client interface and Control Center

Version 2.0.2 (August 2004)

- extensions API for writing commands and reporters in Java
- controlling API for controlling NetLogo from external Java code
- sound extension for making sounds and music

Version 2.0 (December 2003)

- full support for Mac OS X and Linux
- Windows 95, MacOS 8/9 no longer supported
- improved look and feel
- fast, flicker-free, non-grid-based graphics

- primitives for reading and writing external files
- strict math mode for identical results cross−platform
- export view or interface tab as image file
- improved BehaviorSpace
- computer HubNet (no longer alpha)

Version 1.3 (June 2003)

- view control strip
- choosers
- new primitives including `run`, `runresult`, `map`, `foreach`, `filter`, `reduce`
- some primitives accept a variable number of inputs

Version 1.2 (March 2003)

- much improved speed
- computer HubNet (alpha)

Version 1.1 (July 2002)

- "Save as Applet" lets you embed your model in any web page
- printer support
- Procedures menu
- scrollable Interface tab

Version 1.0 (April 2002)

- initial release (after a series of betas)

System Requirements

NetLogo runs on almost any current computer.

If you have any trouble with NetLogo not working, write bugs@ccl.northwestern.edu.

System Requirements: Application

Windows

NetLogo runs on Windows Vista, XP, 2000, NT, ME, and 98.

The NetLogo installer for Windows installs Java version 1.5.0 for NetLogos exclusive use only. Other programs on your computer are not affected.

Mac OS X

Mac OS X 10.4 (or newer) is strongly recommended. 10.3 and 10.2 are also supported.

Please run Software Update to ensure that you have the latest Java.

Other platforms

NetLogo should work on any platform on which a Java Virtual Machine, version 1.4.1 or later, is installed. Version 1.5.0_12 or later is preferred.

You should run NetLogo as follows:

```
java -server -Xms16M -Xmx1024M -Djava.ext.dirs= -jar NetLogo.jar
```

- The `-server` option gives increased performance
- The `-Xm...` options allow NetLogo to use additional RAM.
- The `-Djava...` option ensures that the 3D view uses the version of JOGL bundled with NetLogo.

System Requirements: Saved Applets

NetLogo models saved as Java applets should work in any web browser where Java version 1.4.1 or later is installed.

System Requirements: 3D View

Occasionally an older, less powerful system is not able to successfully use the 3D view. Try it and see.

Some systems can use the 3D window but can't switch to 3D fullscreen mode. It depends on the graphics card and controller. For example, the ATI Radeon IGP 345 and Intel 82845 probably will not work.

Known Issues

If NetLogo malfunctions, please send us a bug report. See the "Contacting Us" section for instructions.

Known bugs (all systems)

Language/engine bugs

- The array and table extensions are only partially compatible with the importing worlds feature. When you export a NetLogo world (using the `export-world` command or Export World menu item), arrays and tables are exported "by value". This means that if you have the same array or table stored in more than one location, then when it is exported and re-imported, there will now be a distinct arrays or tables in each of the places the original array or table appeared. These duplicates will initially contain the same values, but if one duplicate is altered, the others will not change.
- "Export World" does not save the state of any open files used by the file primitives. If you have a file open, export the world, and then import that world into NetLogo, you will need to re-open that file before resuming the run.
- A bug in Java causes patch colors imported using `import-pcolors` to be brighter than the original if the original image has a grayscale palette. To work around this issue, convert the image file to an RGB palette.

Other bugs

- Out-of-memory conditions are not handled gracefully
- the "Snap to Grid" feature is disabled when zoomed in or out
- Drawing and then erasing a line in the drawing may not erase every pixel exactly.
- Extensions that require additional external jars don't work from models saved as applets (we are already working on fixing this)
- The 3D View doesn't work on some graphics configurations; on others the 3D View works but 3D full screen mode doesn't
- When running a model headless (from the command line), if the model was created in an earlier NetLogo version, it may not work properly. Use the GUI to open and resave the model in the current NetLogo version before running it headless.

Windows-only bugs

- The "User Manual" item on the Help menu does not work on every machine (Windows 98 and ME are most likely to be affected, newer Windows versions less so)
- On some laptops, the Procedures and Info tabs may become garbled when you scroll them. To avoid this bug, reduce the size of the NetLogo window and/or reduce the color depth of your monitor (e.g. change from 32-bit to 16- or 8-bit color). This is a bug in Java itself, not in NetLogo per se. For technical details on the bug, see http://developer.java.sun.com/developer/bugParade/bugs/4763448.html (free registration required). NetLogo users are encouraged to visit that site and vote for Sun to fix this bug.

Macintosh−only bugs

- When opening a model from the Finder (by double−clicking on it, or dragging it onto the NetLogo icon), if NetLogo is not already running, then the model may or may not open; the bug is intermittent. (If NetLogo is already running, the model always opens.)
- On Mac OS X 10.4 only, the "Copy View" and "Copy Interface" items may not work: the resulting image is distorted. The workaround is to use the "Export View" and "Export Interface" items instead. This issue will go away if you use Software Update to get the latest Java from Apple.
- On versions of Mac OS X prior to 10.4, it is possible for NetLogo's menus to get confused so that the "Quit" item does not work. If this happens, you can quit NetLogo by pressing the red close button on the left end of the NetLogo's title bar.

Linux/UNIX−only bugs

- User Manual always opens in Mozilla, not your default browser. One possible workaround is to bookmark the file docs/index.html in your favorite browser. Another workaround is to make a symlink that's called "mozilla" (that's the command name NetLogo tries to run), but actually runs a different browser.
- We have discovered a problem on Linux where the "exp" reporter sometimes returns a slightly different answer (differing only in the last decimal place) for the same input. According to an engineer at Sun, this should only happen on Linux kernel versions 2.4.19 and earlier, but we have observed the problem on more recent kernel versions. We assume the problem is Linux−specific and does not happen on other Unix−based systems. We are not sure if the problem ever occurs in practice during actual NetLogo model runs, or only occurs in the context of our testing regimen. The bug in the Sun's Java VM, and not in NetLogo itself. We hope that only the "exp" reporter is affected, but we can't be entirely certain of this. NetLogo users are encouraged to visit http://developer.java.sun.com/developer/bugParade/bugs/5023712.html (free registration required) and vote for Sun to fix this bug.
- If NetLogo cannot find the font Lucida, menus will be illegible. This has been known to happen on Fedora Core 3, after upgrading packages. Restarting the X Font Server (xfs) has resolved the problem in all reported cases.
- Sun's 1.5.0 Java runtime has display problems with GTK 2.0 and NetLogo. Issues may include windows not updating properly, interface elements being strangely sized, menus being cut−off at the bottom, and weird characters appearing on the view. To avoid these issues, upgrade to Java 1.6.

Known issues with computer HubNet

See the HubNet Guide for a list of known issues with computer HubNet.

Contacting Us

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you.

Web Site

Our web site at ccl.northwestern.edu includes our mailing address and phone number. It also has information about our staff and our various research activities.

Feedback, Questions, Etc.

If you need help with your model, consider posting to the NetLogo users group at http://groups.yahoo.com/group/netlogo−users/.

We also have a group specifically for educators at http://groups.yahoo.com/group/netlogo−educators/.

If you have feedback, suggestions, or questions, write us at feedback@ccl.northwestern.edu.

Reporting Bugs

If you would like to report a bug that you find in NetLogo, write to bugs@ccl.northwestern.edu. When submitting a bug report, please try to include as much of the following information as possible:

- A complete description of the problem and how it occurred.
- The NetLogo model or code you are having trouble with. If possible, attach a complete model.
- Your system information: NetLogo version, OS version, Java version, and so on. (This information is available from NetLogo's "About NetLogo" menu item, then clicking the System tab. In saved applets, the same information is available by control−clicking (Mac) or right−clicking the white background of the applet.)
- Any error messages that were displayed.

Sample Model: Party

This activity is designed to get you thinking about computer modeling and how you can use it. It also gives you some insight into the NetLogo software. We encourage beginning users to start with this activity.

At a Party

Have you ever been at a party and noticed how people cluster in groups? You may have also noticed that people do not stay within one group, but move throughout the party. As individuals move around the party, the groups change. If you watched these changes over time, you would notice patterns forming.

For example, in social settings, people tend to exhibit different behavior than when they are at work or home. Individuals who are confident within their work environment may become shy and timid at a social gathering. And others who are quiet and reserved at work may be the "party starter" with friends.

The patterns may also depend on what kind of gathering it is. In some settings, people are trained to organize themselves into mixed groups; for example, party games or school−like activities. But in a non−structured atmosphere, people tend to group in a more random manner.

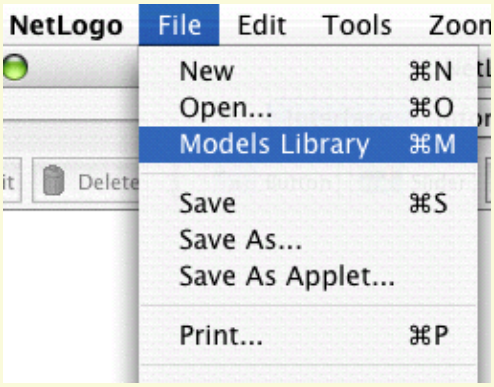
Is there any type of pattern to this kind of grouping?

Let's take a closer look at this question by using the computer to model human behavior at a party. NetLogo's "Party" model looks specifically at the question of grouping by gender at parties: why do groups tend to form that are mostly men, or mostly women?

Let's use NetLogo to explore this question.

What to do:

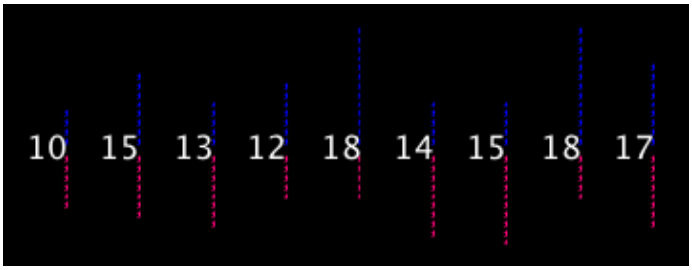
1. Start NetLogo.
2. Choose "Models Library" from the File menu.



3. Open the "Social Science" folder.
4. Click on the model called "Party".

5. Press the "open" button.
6. Wait for the model to finish loading
7. (optional) Make the NetLogo window bigger so you can see everything.
8. Press the "setup" button.

In the view, you will see pink and blue lines with numbers:



These lines represent mingling groups at a party. Men are represented in blue, women in pink. The numbers are the total number of people in each group.

Do all the groups have about the same number of people?

Do all the groups have about the same number of each sex?

Let's say you are having a party and invited 150 people. You are wondering how people will gather together. Suppose 10 groups form at the party.

How do you think they will group?

Instead of asking 150 of your closest friends to gather and randomly group, let's have the computer simulate this situation for us.

What to do:

1. Press the "go" button. (Pressing "go" again will stop the model manually.)
2. Observe the movement of people until the model stops.
3. Watch the plots to see what's happening in another way.

Now how many people are in each group?

Originally, you may have thought 150 people splitting into 10 groups, would result in about 15 people in each group. From the model, we see that people did not divide up evenly into the 10 groups −− instead, some groups became very small, whereas other groups became very large. Also, the party changed over time from all mixed groups of men and women to all single−sex groups.

What could explain this?

There are lots of possible answers to this question about what happens at real parties. The designer of this simulation thought that groups at parties don't just form randomly. The groups are determined by how the individuals at the party behave. The designer chose to focus on a particular variable, called "tolerance":

Tolerance is defined here as the percentage of people of the opposite sex an individual is "comfortable" with. If the individual is in a group that has a higher percentage of people of the opposite sex than their tolerance allows, then they become "uncomfortable" and leave the group to find another group.

For example, if the tolerance level is set at 25%, then males are only "comfortable" in groups that are less than 25% female, and females are only "comfortable" in groups that are less than 25% male.

As individuals become "uncomfortable" and leave groups, they move into new groups, which may cause some people in that group to become "uncomfortable" in turn. This chain reaction continues until everyone at the party is "comfortable" in their group.

Note that in the model, "tolerance" is not fixed. You, the user, can use the tolerance "slider" to try different tolerance percentages and see what the outcome is when you start the model over again.

How to start over:

1. If the "go" button is pressed (black), then the model is still running. Press the button again to stop it.
2. Adjust the "tolerance" slider to a new value by dragging its red handle.
3. Press the "setup" button to reset the model.
4. Press the "go" button to start the model running again.

Challenge

As the host of the party, you would like to see both men and women mingling within the groups. Adjust the tolerance slider on the side of the view to get all groups to be mixed as an end result.

To make sure all groups of 10 have both sexes, at what level should we set the tolerance?

Test your predictions on the model.

Can you see any other factors or variables that might affect the male to female ratio within each group?

Make predictions and test your ideas within this model. Feel free to manipulate more than one variable at a time.

As you are testing your hypotheses, you will notice that patterns are emerging from the data. For example, if you keep the number of people at the party constant but gradually increase the

tolerance level, more mixed groups appear.

How high does the tolerance value have to be before you get mixed groups?

What percent tolerance tends to produce what percentage of mixing?

Thinking With Models

Using NetLogo to model situations like this party scenario allows you to experiment with a system in a rapid and flexible way that would be difficult to do in a real world situation. Modeling also gives you the opportunity to observe a situation or circumstance with less prejudice −− as you can examine the underlying dynamics of a situation. You may find that as you model more and more, many of your preconceived ideas about various phenomena will be challenged. For example, a surprising result of the Party model is that even if tolerance is relatively high, a great deal of separation between the sexes occurs.

This is a classic example of an "emergent" phenomenon, where a group pattern results from the interaction of many individuals. This idea of "emergent" phenomena can be applied to almost any subject.

What other emergent phenomena can you think of?

To see more examples and gain a deeper understanding of this concept and how NetLogo helps learners explore it, you may wish to explore NetLogo's Models Library. It contains models that demonstrate these ideas in systems of all kinds.

For a longer discussion of emergence and how NetLogo helps learners explore it, see "Modeling Nature's Emergent Patterns with Multi−agent Languages" (Wilensky, 2001).

What's Next?

The section of the User Manual called Tutorial #1: Running Models goes into more detail about how to use the other models in the Models Library.

If you want to learn how to explore the models at a deeper level, Tutorial #2: Commands will introduce you to the NetLogo modeling language.

Eventually, you'll be ready for Tutorial #3: Procedures, where you can learn how to alter and extend existing models to give them new behaviors, and build your own models.

Tutorial #1: Models

If you read the Sample Model: Party section, you got a brief introduction to what it's like to interact with a NetLogo model. This section will go into more depth about the features that are available while you're exploring the models in the Models Library.

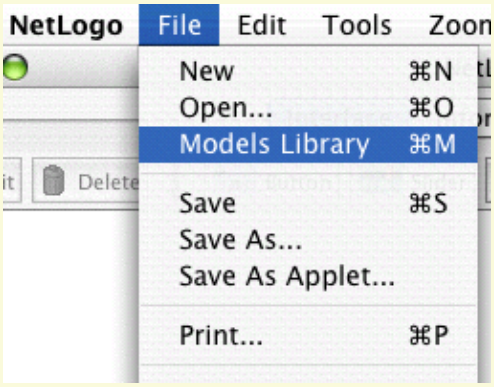
Throughout all of the tutorials, we'll be asking you to make predictions about what the effects of making changes to the models will be. Keep in mind that the effects are often surprising. We think these surprises are exciting and provide excellent opportunities for learning.

Some people have found it helpful to print out the tutorials in order to work through them. When the tutorials are printed out, there's more room on your computer screen for the NetLogo model you're looking at.

Sample Model: Wolf Sheep Predation

We'll open one of the Sample Models and explore it in detail. Let's try a biology model: Wolf Sheep Predation, a predator−prey population model.

- Open the Models Library from the File menu.



- Choose "Wolf Sheep Predation" from the Biology section and press "Open".

The Interface tab will fill up with lots of buttons, switches, sliders and monitors. These interface elements allow you to interact with the model. Buttons are blue; they set up, start, and stop the model. Sliders and switches are green; they alter model settings. Monitors and plots are beige; they display data.

If you'd like to make the window larger so that everything is easier to see, you can use the zoom menu at the top of the window.

When you first open the model, you will notice that the view is empty (all black). To begin the model, you will first need to set it up.

- Press the "setup" button.

What do you see appear in the view?

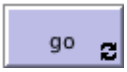
- Press the "go" button to start the simulation.

As the model is running, what is happening to the wolf and sheep populations?

- Press the "go" button to stop the model.

Controlling the Model: Buttons

When a button is pressed, the model responds with an action. A button can be a "once" button, or a "forever" button. You can tell the difference between these two types of buttons by a symbol on the face of the button. Forever buttons have two arrows in the bottom right corners, like this:



Once buttons don't have the arrows, like this:

Once buttons do one action and then stop. When the action is finished, the button pops back up.

Forever buttons do an action over and over again. When you want the action to stop, press the button again. It will finish the current action, then pop back up.

Most models, including Wolf Sheep Predation, have a once button called "setup" and a forever button called "go". Many models also have a once button called "go once" or "step once" which is like "go" except that it advances the model by one tick (time step) instead of over and over. Using a once button like this lets you watch the progress of the model more closely.

Stopping a forever button is the normal way to stop a model. It's safe to pause a model by stopping a forever button, then make it go on by pressing the button again. You can also stop a model with the "Halt" item on the Tools menu, but you should only do this if the model is stuck for some reason. Using "Halt" may interrupt the model in the middle of an action, and as the result the model could get confused.

- If you like, experiment with the "setup" and "go" buttons in the Wolf Sheep Predation model.

Do you ever get different results if you run the model several times with the same settings?

Controlling speed: Speed Slider

The speed slider allows you to control the speed of a model, that is, the speed at which turtles move, patches change color, and so on.

When you move the slider to the left the model slows down so there are longer pauses between each tick (time step). That makes it easier to see what is happening. You might even slow the model down so far as to see exactly what a single turtle is doing.

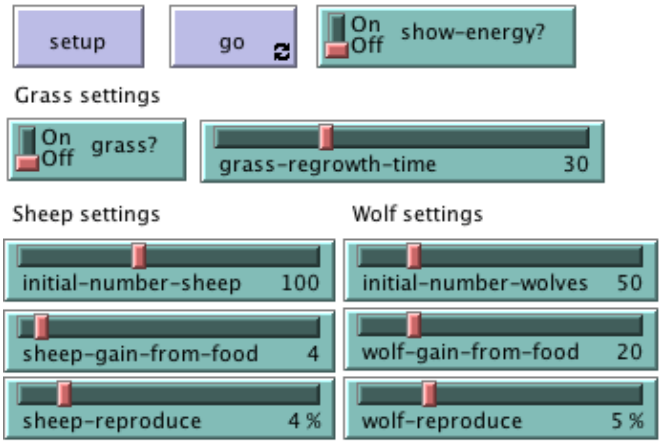
When you move the speed slider to the right of the center the model will speed up. NetLogo will start skipping frames, that is, it won't update the view at the end of every tick, only some ticks. Showing the state of the world takes time, so showing it less often means the model progresses faster.

Note that if you push the speed slider well to the right, the view update may update so frequently that the model appears to have slowed down. It hasn't, as you can see by watching the tick counter. Only the frequency of updates has lessened.

Adjusting Settings: Sliders and Switches

The settings within a model give you an opportunity to work out different scenarios or hypotheses. Altering the settings and then running the model to see how it reacts to those changes can give you a deeper understanding of the phenomena being modeled. Switches and sliders give you access to a model's settings.

Here are the switches and sliders in Wolf Sheep Predation:



Let's experiment with their effect on the behavior of the model.

- Open Wolf Sheep Predation if it's not open already.
- Press "setup" and "go" and let the model run for about a 100 time−ticks. (Note: there is a readout of the number of ticks right above the plot.)
- Stop the model by pressing the "go" button.

What happened to the sheep over time?

Let's take a look and see what would happen to the sheep if we change one of the settings.

- Turn the "grass?" switch on.
- Press "setup" and "go" and let the model run for a similar amount of time as before.

What did this switch do to the model? Was the outcome the same as your previous run?

Just like buttons, switches have information attached to them. Their information is set up in an on/off format. Switches turn on/off a separate set of directions. These directions are usually not necessary for the model to run, but might add another dimension to the model. Turning the "grass?" switch on affected the outcome of the model. Prior to this run, the growth of the grass stayed constant. This is not a realistic look at the predator−prey relationship; so by setting and turning on a grass growth rate, we were able to model all three factors: sheep, wolf and grass populations.

Another type of setting is called a slider.

Sliders are a different type of setting then a switch. A switch has two values: on or off. A slider has a range of numeric values that can be adjusted. For example, the "initial−number−sheep" slider has a minimum value of 0 and a maximum value of 250. The model could run with 0 sheep or it could run with 250 sheep, or anywhere in between. Try this out and see what happens. As you move the marker from the minimum to the maximum value, the number on the right side of the slider changes; this is the number the slider is currently set to.

Let's investigate Wolf Sheep Predation's sliders.

- Read the contents of the Information tab, located above the toolbar, to learn what each of this models' sliders represents.

The Information tab offers guidance and insight into the model. Within this tab you will find an explanation of the model, suggestions on things to try, and other information. You may want to read the Information tab before running a model, or you might want to just start experimenting, then look at the Information tab later.

What would happen to the sheep population if there was more initial sheep and less initial wolves at the beginning of the simulation?

- Turn the "grass?" switch off.
- Set the "initial−number−sheep" slider to 100.
- Set the "initial−number−wolves" slider to 20.
- Press "setup" and then "go".
- Let the model run for about 100 time−ticks.

Try running the model several times with these settings.

What happened to the sheep population?

Did this outcome surprise you? What other sliders or switches can be adjusted to help out the sheep population?

- Set "initial−number−sheep" to 80 and "initial−number−wolves" to 50. (This is close to how they were when you first opened the model.)
- Set "sheep−reproduce" to 10.0%.
- Press "setup" and then "go".
- Let the model run for about 100 time ticks.

What happened to the wolves in this run?

When you open a model, all the sliders and switches are on a default setting. If you open a new model or exit the program, your changed settings will not be saved, unless you choose to save them.

(Note: in addition to sliders and switches, some models have a third kind of setting, called a chooser. The Wolf Sheep Predation doesn't have any of these, though.)

Gathering Information: Plots and Monitors

A purpose to modeling is to gather data on a subject or topic that would be very difficult to do in a laboratory situation. NetLogo has two main ways of displaying data to the user: plots and monitors.

Plots

The plot in Wolf Sheep Predation contains three lines: sheep, wolves, and grass / 4. (The grass count is divided by four so it doesn't make the plot too tall.) The lines show what's happening in the model over time. To see which line is which, click on "Pens" in the upper right corner of the plot window to open the plot pens legend. A key appears that indicates what each line is plotting. In this case, it's the population counts.

When a plot gets close to becoming filled up, the horizontal axis increases in size and all of the data from before gets squeezed into a smaller space. In this way, more room is made for the plot to grow.

If you want to save the data from a plot to view or analyze it in another program, you can use the "Export Plot" item on the File menu. It saves this information to your computer in a format that can by read back by spreadsheet and database programs such as Excel. You can also export a plot by

control−clicking (Mac) or right−clicking (Windows) it and choosing "Export..." from the popup menu.

Monitors

Monitors are another method of displaying information in a model. Here are the monitors in Wolf Sheep Predation:

The monitor labeled "time−ticks" tells us how much time has passed in the model. The other monitors show us the population of sheep and wolves, and the amount of grass. (Remember, the amount of grass is divided by four to keep the plot from getting too tall.)

The numbers displayed in the monitors update continuously as the model runs, whereas the plots show you data from the whole course of the model run.

Note that NetLogo has also another kind of monitor, called "agent monitors". These will be introduced in Tutorial #2.

Controlling the View

If you look at the interface tab, you'll see a strip of controls along the top edge in the toolbar. These controls change various aspects of the view.

Let's experiment with the effect of these controls.

- Press "setup" and then "go" to start the model running.
- As the model runs, move the speed slider to the left.

What happens?

This slider is helpful if a model is running too fast for you to see what's going on in detail.

- Move the speed slider to the middle.
- Try moving the speed slider to the right.
- Now try checking and unchecking the view updates checkbox.

What happens?

Fast forwarding the model and turning off view updates are useful if you're impatient and want a model to run faster. Fast forwarding (moving the speed slider to the right) drops view updates so the model can run fast, since updating the view takes time that could be used for updating the view.

When view updates are off completely The model continues to run in the background, and plots and monitors still update; but if you want to see what's happening, you need to turn view updates back

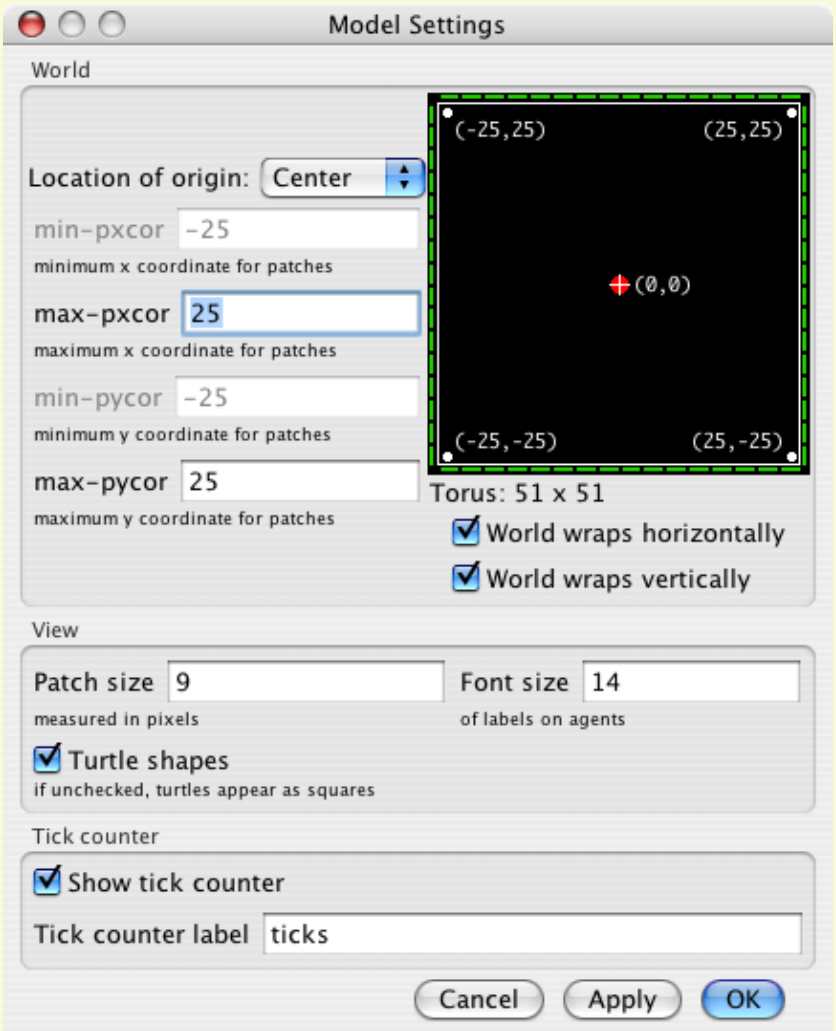
on by rechecking the box. Most models run much faster when view updates are off.

The size of the view is determined by five separate settings: Min and Max X, Min and Max Y and Patch Size. Let's take a look at what happens when we change the size of the view in the "Wolf Sheep Predation" model.

There are more world and view settings than there's room for in the toolbar. The "Settings..." button lets you get to the rest of the settings.

- Press the "Settings..." button in the toolbar.

A dialog box will open containing all the settings for the view:



What are the current settings for max−pxcor, min−pxcor, max−pycor, min−pycor, and Patch size?

- Press "cancel" to make this window go away without changing the settings.
- Place your mouse pointer next to, but still outside of, the view.

You will notice that the pointer turns into a crosshair.

- Hold down the mouse button and drag the crosshair over the view.

The view is now selected, which you know because it is now surrounded by a gray border.

- Drag one of the square black "handles". The handles are found on the edges and at the corners of the view.
- Unselect the view by clicking anywhere in the white background of the Interface tab.
- Press the "Settings..." button again and look at the settings.

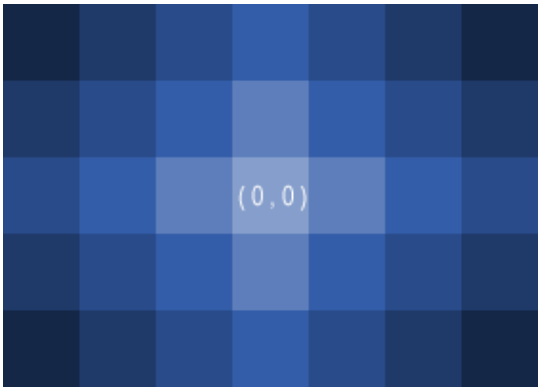
What numbers changed?

What numbers didn't change?

The NetLogo world is a two dimensional grid of "patches". Patches are the individual squares in the grid.

In Wolf Sheep Predation, when the "grass?" switch is on the individual patches are easily seen, because some of them are green, while others are brown.

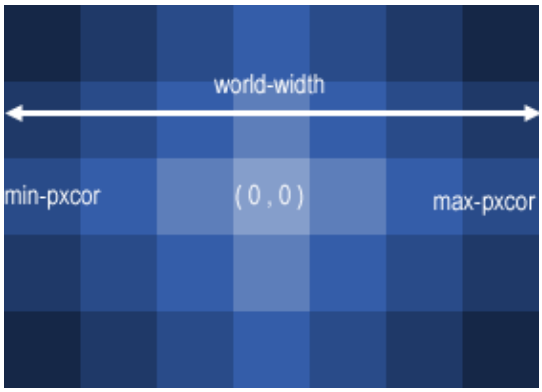
Think of the patches as being like square tiles in a room with a tile floor. By default, exactly in the middle of the room is a tile labeled (0,0); meaning that if the room was divided in half one way and then the other way, these two dividing lines would intersect on this tile. We now have a coordinate system that will help us locate objects within the room:

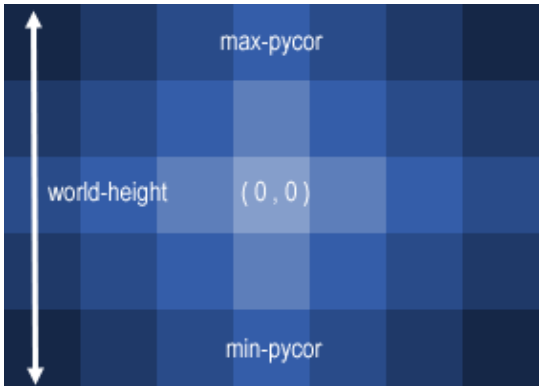


How many tiles away is the (0,0) tile from the right side of the room?

How many tiles away is the (0,0) tile from the left side of the room?

In NetLogo, the number of tiles from right to left is called world−width. And the number of tiles from top to bottom is world−height. These numbers are defined by top, bottom, left and right boundaries.





In these diagrams, max−pxcor is 3 , min−pxcor is −3, max−pycor is 2 and min−pycor is −2.

When you change the patch size, the number of patches (tiles) doesn't change, the patches only get larger or smaller on the screen.

Let's look at the effect of changing the minimum and maximum coordinates in the world.

- Using the Settings dialog that is still open, change max−pxcor to 30 and max−pycor value to 10. Notice that min−pxcor and min−pycor change too. That's because by default the origin (0,0) is in the center of the world.

What happened to the shape of the view?

- Press the "setup" button.

Now you can see the new patches you have created.

- Edit the view by pressing the "Settings..." button again.
- Change the patch size to 20 and press "OK".

What happened to the size of the view? Did its shape change?

Editing the view also lets you change other settings, including the font size of labels and whether the view uses shapes. Feel free to experiment with these and other settings as well.

Once you are done exploring the Wolf Sheep Predation model, you may want to take some time just to explore some of the other models available in the Models Library.

The Models Library

The library contains five sections: Sample Models, Perspective Demos, Curricular Models, Code Examples, and HubNet Computer Activities.

Sample Models

The Sample Models section is organized by subject area and currently contains more than 210 models. We are continuously working on adding new models to it, so come visit this section at a later date to view the new additions to the library.

Some of the folders in Sample Models have folders inside them labeled "(unverified)". These models are complete and functional, but are still in the process of being reviewed for content, accuracy, and quality of code.

Perspective Demos

These models are all models that are also in Sample Models, however, they are slightly modified to demonstrate NetLogo's perspective features.

Curricular Models

These are models designed to be used in schools in the context of curricula developed by the CCL at Northwestern University. Some of these are models are also listed under Sample Models; others are unique to this section. See the info tabs of the models for more information on the curricula they go with.

Code Examples

These are simple demonstrations of particular features of NetLogo. They'll be useful to you later when you're extending existing models or building new ones. For example, if you wanted to put a histogram within your model, you'd look at "Histogram Example" to find out how.

HubNet Computer Activities

This section contains participatory simulations for use in the classroom. For more information about HubNet, see the HubNet Guide.

What's Next?

If you want to learn how to explore models at a deeper level, Tutorial #2: Commands will introduce you to the NetLogo modeling language.

In Tutorial #3: Procedures you can learn how to alter and extend existing models and build your own models.

Tutorial #2: Commands

In Tutorial #1, you had the opportunity to view some of the NetLogo models, and you have successfully navigated your way through opening and running models, pressing buttons, changing slider and switch values, and gathering information from a model using plots and monitors. In this section, the focus will start to shift from observing models to manipulating models. You will start to see the inner workings of the models and be able to change how they look.

Sample Model: Traffic Basic

- Go to the Models Library (File menu).
- Open up Traffic Basic, found in the "Social Science" section.
- Run the model for a couple minutes to get a feel for it.
- Consult the Information tab for any questions you may have about this model.

In this model, you will notice one red car in a stream of blue cars. The stream of cars are all moving in the same direction. Every so often they "pile up" and stop moving. This is modeling how traffic jams can form without any cause such as an accident, a broken bridge, or an overturned truck. No "centralized cause" is needed for a traffic jam to form.

You may alter the settings and observe a few runs to get a full understanding of the model.

As you are using the Traffic Basic model, have you noticed any additions you would like to make to the model?

Looking at the Traffic Basic model, you may notice the environment is fairly simple; a black background with a white street and number of blue cars and one red car. Changes that could be made to the model include: changing the color and shape of the cars, adding a house or street light, creating a stop light, or even creating another lane of traffic. Some of these suggested changes are cosmetic and would enhance the look of the model while the others are more behavioral. We will be focusing more on the simpler or cosmetic changes throughout most of this tutorial. (Tutorial #3 will go into greater detail about behavioral changes, which require changing the Procedures tab.)

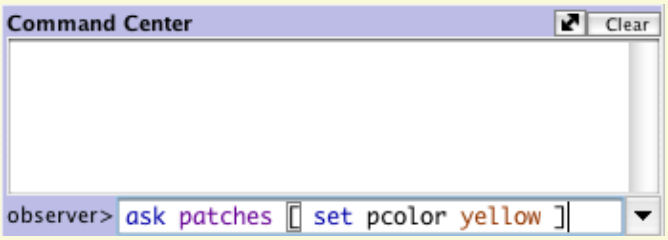
To make these simple changes we will be using the Command Center.

The Command Center

The Command Center is located in the Interface Tab and allows you to enter commands or directions to the model. Commands are instructions you can give to NetLogo's agents: turtles, patches, links, and the observer. (Refer to the Interface Guide for details explaining the different parts of the Command Center.)

In Traffic Basic:

- Press the "setup" button.
- Locate the Command Center.
- Click the mouse in the white box at the bottom of the Command Center.
- Type the text shown here:



- Press the return key.

What happened to the View?

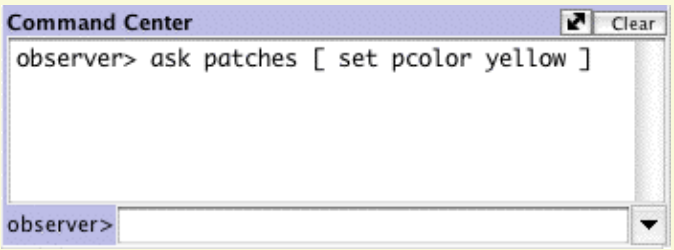
You may have noticed the background of the View has turned all yellow and the street has disappeared.

Why didn't the cars turn yellow too?

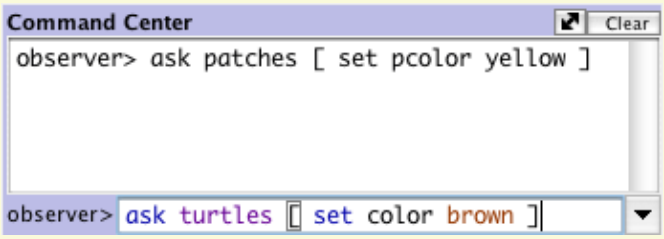
Looking back at the command that was written, we asked only the patches to change their color. In this model, the cars are represented by a different kind of agent, called "turtles". Therefore, the cars did not received these instructions and thus did not change.

What happened in the Command Center?

You may have noticed that the command you just typed is now displayed in the white box in the middle of the Command Center as shown below:



- Type in the white box at the bottom of the Command Center the text shown below:



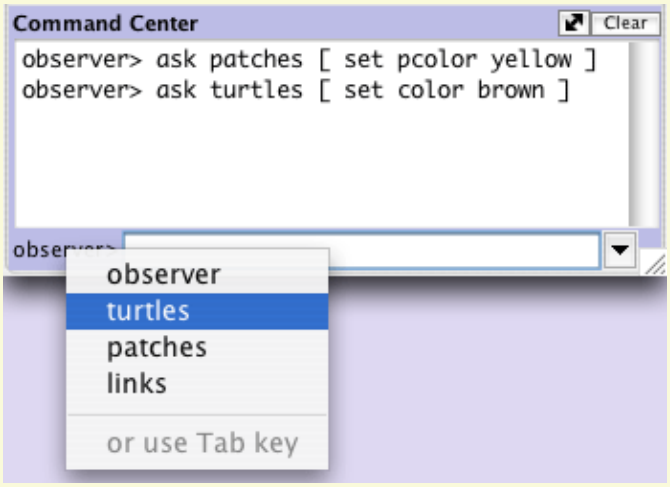
Was the result what you expected?

Your View should have a yellow background with a line of brown cars in the middle:

The NetLogo world is a two dimensional world that is made up of turtles, patches and an observer. The patches create the ground in which the turtles can move around on and the observer is a being that oversee everything that is going on in the world. (For a detailed description and specifics about this world, refer to the NetLogo Programming Guide.)

In the Command Center, we have the ability to give the observer a command, the turtles a command, or the patches a command. We choose between these options by using the popup menu located in the bottom left corner of the Command Center. You can also use the tab key on your keyboard to cycle through the different options.

- In the Command Center, click on the "observer>" in the bottom left corner:



- Choose "turtles" from the popup menu.
- Type `set color pink` and press return.
- Press the tab key until you see "patches>" in the bottom left corner.
- Type `set pcolor white` and press return.

What does the View look like now?

Do you notice any differences between these two commands and the observer commands from earlier?

The observer oversees the world and therefore can give a command to the patches or turtles using `ask`. Like in the first example (observer> `ask patches [set pcolor yellow]`), the observer has to ask the patches to set their pcolor to yellow. But when a command is directly given to a group of agents like in the second example (patches> `set pcolor white`), you only have to give the command itself.

- Press "setup".

What happened?

Why did the View revert back to the old version, with the black background and white road? Upon pressing the "setup" button, the model will reconfigure itself back to the settings outlined in the Procedures tab. The Command Center is not often used to permanently change the model. It is most often used as a tool to customize current models and allows for you to manipulate the NetLogo world to further answer those "What if" questions that pop up as you are investigating the models. (The Procedures tab is explained in the next tutorial, and in the Programming Guide.)

Now that we have familiarized ourselves with the Command Center, let's look at some more details about how colors work in NetLogo.

Working With Colors

You may have noticed in the previous section that we used two different words for changing color: `color` and `pcolor`.

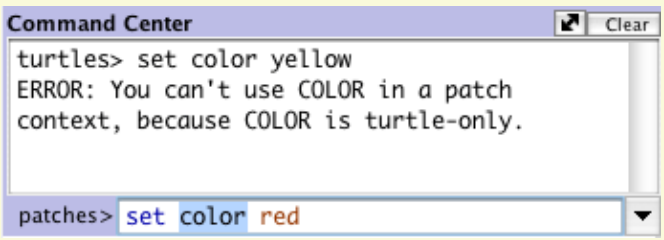
What is the difference between color and pcolor?

- Choose "turtles" from the popup menu in the Command Center (or use the tab key).
- Type `set color blue` and press return.

What happened to the cars?

Think about what you did to make the cars turn blue, and try to make the patches turn red.

If you try to ask the patches to `set color red`, an error message occurs:


Command Center
Clear
turtles> set color yellow
ERROR: You can't use COLOR in a patch
context, because COLOR is turtle-only.
patches> set color red

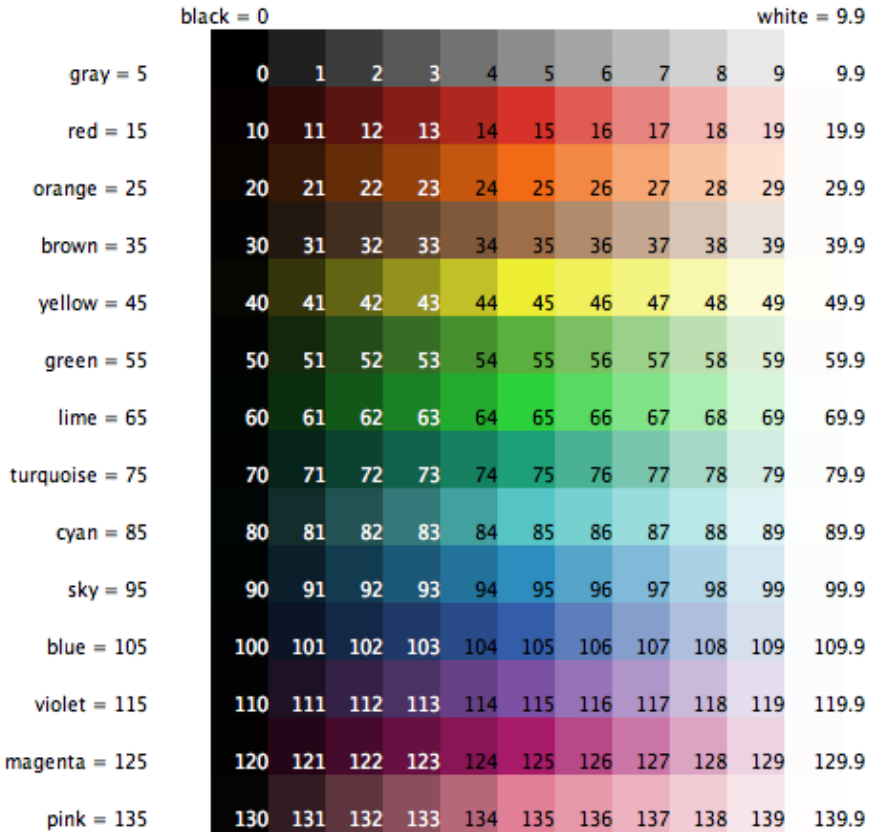
- Type `set pcolor red` instead and press return.

We call `color` and `pcolor` "variables". Some commands and variables are specific to turtles and some are specific to patches. For example, the `color` variable is a turtle variable, while the `pcolor` variable is a patch variable.

Go ahead and practice altering the colors of the turtles and patches using the `set` command and these two variables.

To be able to make more changes to the colors of turtles and patches, or shall we say cars and backgrounds, we need to gain a little insight into how NetLogo deals with colors.

In NetLogo, all colors have a numeric value. In all of the exercises we have been using the name of the color. This is because NetLogo recognizes 16 different color names. This does not mean that NetLogo only recognizes 16 colors. There are many shades in between these colors that can be used too. Here's a chart that shows the whole NetLogo color space:



To get a color that doesn't have its own name, you just refer to it by a number instead, or by adding or subtracting a number from a name. For example, when you type `set color red`, this does the same thing as if you had typed `set color 15`. And you can get a lighter or darker version of the same color by using a number that is a little larger or a little smaller, as follows.

- Choose "patches" from the popup menu in the Command Center (or use the tab key).
- Type `set pcolor red − 2` (The spacing around the "−" is important.)

By subtracting from red, you make it darker.

- Type `set pcolor red + 2`

By adding to red, you make it lighter.

You can use this technique on any of the colors listed in the chart.

Agent Monitors and Agent Commanders

In the previous activity, we used the set command to change the colors of all the cars. But if you recall, the original model contained one red car amongst a group of blue cars. Let's look at how to change only one car's color.

- Press "setup" to get the red car to reappear.
- If you are on a Macintosh, hold down the Control key and click on the red car. On other operating systems, click on the red car with the right mouse button.
- If there is another turtle close to the red turtle you'll see more than one turtle listed at the bottom of the menu. Move your mouse over the turtle selections, notice when your mouse highlights a turtle menu item that turtle is highlighted in the view. Select "inspect turtle" from the sub−menu for the red turtle.

A turtle monitor for that car will appear:

Taking a closer look at this turtle monitor, we can see all of the variables that belong to the red car. A variable is a place that holds a value that can be changed. Remember when it was mentioned that all colors are represented in the computer as numbers? The same is true for the agents. For example, every turtle has an ID number we call its "who number".

Let's take a closer look at the turtle monitor:

What is this turtle's who number?

What color is this turtle?

What shape is this turtle?

This turtle monitor is showing a turtle who that has a who number of 0, a color of 15 (red −− see above chart), and the shape of a car.

There are two other ways to open a turtle monitor besides right−clicking (or control−clicking, depending on your operating system). One way is to choose "Turtle Monitor" from the Tools menu, then type the who number of the turtle you want to inspect into the "who" field and press return. The other way is to type `inspect turtle 0` (or other who number) into the Command Center.

You close a turtle monitor by clicking the close box in the upper left hand corner (Macintosh) or upper right hand corner (other operating systems).

Now that we know more about Agent Monitors, we have three ways to change an individual turtle's color.

One way is to use the box called an Agent Commander found at the bottom of an Agent Monitor. You type commands here, just like in the Command Center, but the commands you type here are only done by this particular turtle.

- In the Agent Commander of the Turtle Monitor for turtle 0, type `set color pink`.

What happens in the View?

Did anything change in the Turtle Monitor?

A second way to change one turtle's color is to go directly to the color variable in the Turtle Monitor and change the value.

- Select the text to the right of "color" in the Turtle Monitor.
- Type in a new color such as `green + 2`.

What happened?

The third way to change an individual turtle's or patch's color is to use the observer. Since, the observer oversees the NetLogo world, it can give commands that affect individual turtles, as well as groups of turtles.

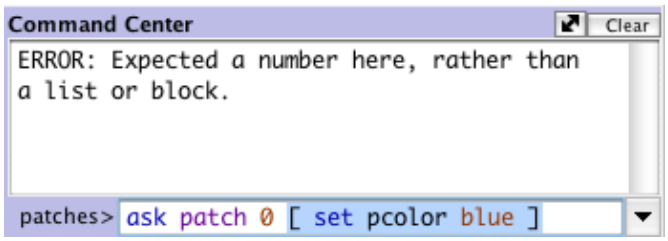
- In the Command Center, select "observer" from the popup menu (or use the tab key).
- Type `ask turtle 0 [set color blue]` and press return.

What happens?

Just as there are Turtle Monitors, there are also Patch Monitors. Patch monitors work very similarly to Turtle Monitors.

Can you make a patch monitor and use it to change the color of a single patch?

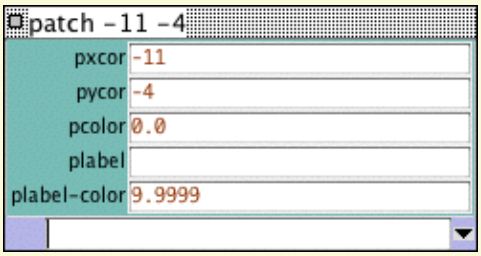
If you try to have the observer `ask patch 0 [set pcolor blue]`, you'll get an error message:



To ask an individual turtle to do something, we use its who number. But patches don't have who numbers, therefore we need to refer to them some other way.

Remember, patches are arranged on a coordinate system. Two numbers are needed to plot a point on a graph: an x−axis value and a y−axis value. Patch locations are designated in the same way as plotting a point.

- Open a patch monitor for any patch.



The monitor shows that for the patch in the picture, its `pxcor` variable is −11 and its `pycor` variable is −4. If we go back to the analogy of the coordinate plane and wanted to plot this point, the point would be found in the lower left quadrant of the coordinate plane where x=−11 and y=−4.

To tell this particular patch to change color, use its coordinates.

- In the bottom of the patch monitor, enter `set pcolor blue` and press return.

Typing a command in a turtle or patch monitor addresses only that turtle or patch.

You can also talk to a single patch from the Command Center:

- In the Command Center, enter `ask patch −11 −4 [set pcolor green]` and press return.

What's Next?

At this point, you may want to take some time to try out the techniques you've learned on some of the other models in the Models Library.

In Tutorial #3: Procedures you can learn how to alter and extend existing models and build your own models.

Tutorial #3: Procedures

This tutorial leads you through the process of building a complete model, built up stage by stage, with every step explained along the way.

Agents and procedures

In Tutorial #2, you learned how to use the command center and agent monitors to inspect and modify agents and make them do things. Now you're ready to learn about the real heart of a NetLogo model: the Procedures tab.

You've already used types of agents you can give commands to in NetLogo: patches, turtles, links, and the observer. Patches are stationary and arranged in a grid. Turtles move over that grid. Links connect two turtles. The observer oversees everything that's going on and does whatever the turtles, patches and links can't do for themselves.

All four types of agents can run NetLogo commands. All three can also run "procedures". A procedure combines a series of NetLogo commands into a single new command that you define.

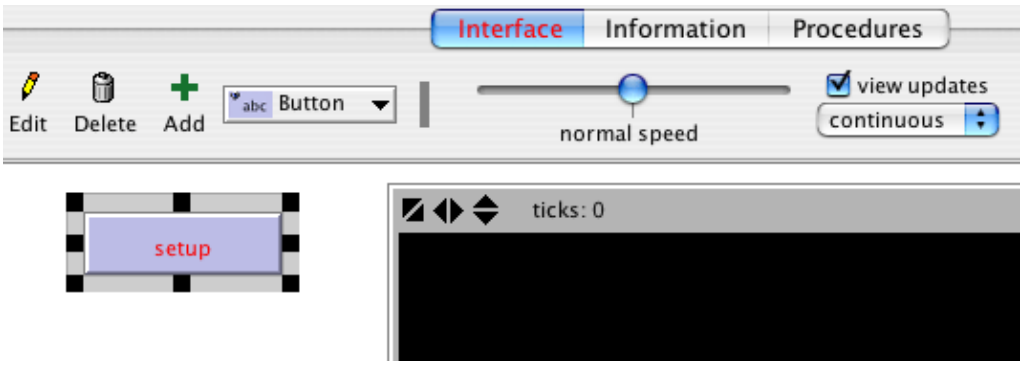
You will now learn to write procedures that make turtles move, eat, reproduce, and die. You will also learn how to make monitors, sliders, and plots. The model we'll build is a simple ecosystem model not unlike parts of Wolf Sheep Predation from Tutorial #1.

Making the setup button

To start a new model, select "New" from the File menu. Then begin by creating a setup button:

- Click the "Button" icon in the toolbar at the top of the Interface tab.
- Click wherever you want the button to appear in the empty white area of the Interface tab.
- A dialog box for editing the button opens. Type `setup` in the box labeled "Commands".
- Press the OK button when you're done; the dialog box closes.

Now you have a setup button. Pressing the button runs a procedure called "setup". A procedure is a sequence of NetLogo commands that we assign a new name. We haven't defined that procedure yet (we will soon). Because the button refers to a procedure that doesn't exist yet, the button turns red:



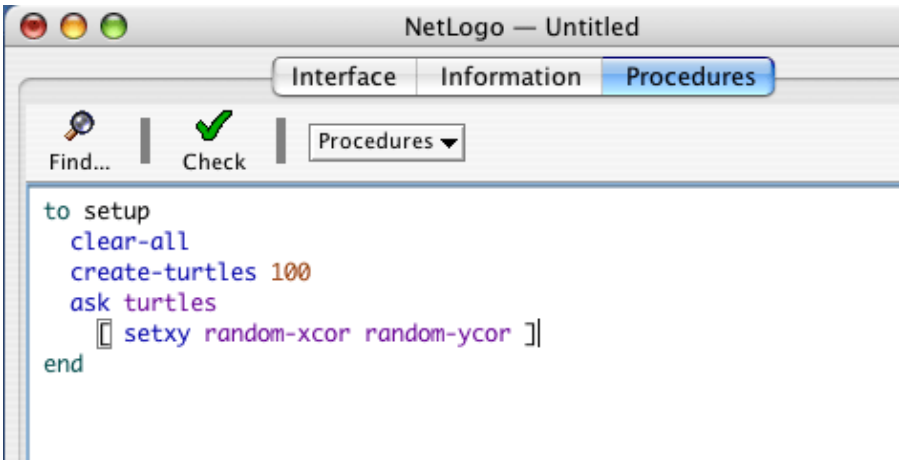
If you want to see the actual error message, click the button.

Now we'll create the "setup" procedure, so the error message will go away:

- Switch to the Procedures tab.
- Type the following:

```
to setup
  clear-all
  create-turtles 100
  ask turtles [ setxy random-xcor random-ycor ]
end
```

When you're done, the Procedures tab looks like this:



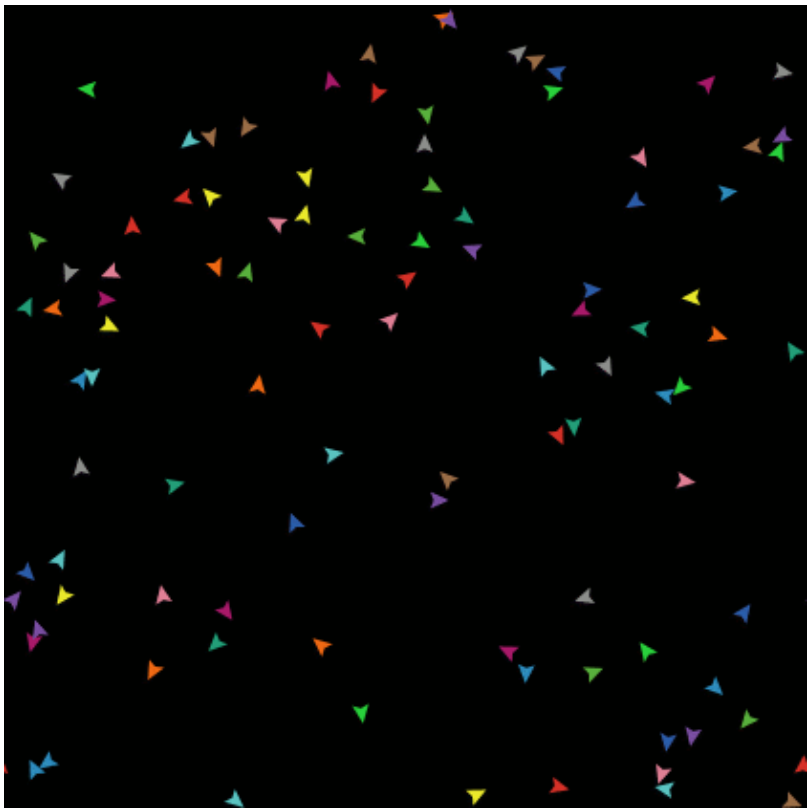
Note that the lines are indented different amounts. Most people find it helpful to indent their code like this, but it is not mandatory. It makes the code easier to read and change. Your procedure began with the word `to` and ended with the word `end`. Every new procedure you create will begin and end with these two words.

Let's look at what you typed in and see what each line of your procedure does:

- `to setup` begins defining a procedure named "setup".

- `clear-all` resets the world to an initial, empty state. All the patches turn black and any turtles you might have created disappear. Basically, it wipes the slate clean for a new model run.
- `create-turtles 100` creates 100 turtles. They start out standing at the origin, that is, the center of patch 0,0.
- `ask turtles [ ... ]` tells each turtle to run, independently, the commands inside the brackets. (Every command in NetLogo is run by some agent. `ask` is a command too. Here, the observer is running the `ask` command itself, in turn causing the turtles to run commands.)
- `setxy random-xcor random-ycor` is a command using "reporters". A reporter, as opposed to a command, reports a result. First each turtle runs the reporter `random-xcor` which will report a random number from the allowable range of turtle coordinates along the X axis. Then each turtle runs the reporter `random-ycor`, same for the Y axis. Finally each turtle runs the `setxy` command with those two numbers as inputs. That makes the turtle move to the point with those coordinates.
- `end` completes the definition of the "setup" procedure.

When you're done typing, switch to the Interface tab and press the setup button you made before. You will see the turtles scattered around the world:



Press setup a couple more times, and see how the arrangement of turtles is different each time. Note that some turtles may be right on top of each other.

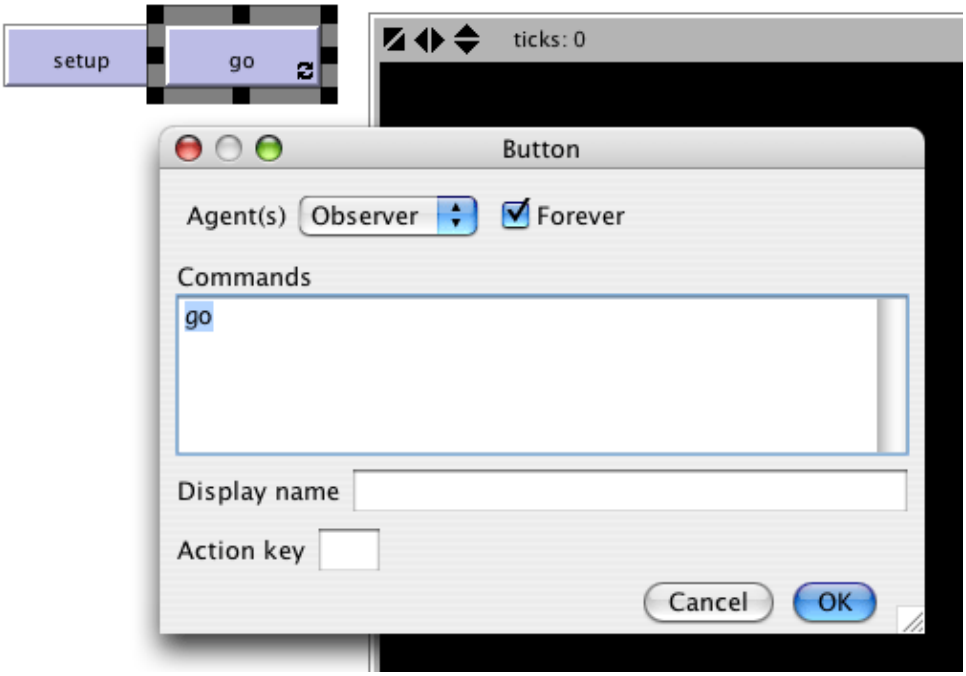
Think a bit about what you needed to do to make this happen. You needed to make a button in the interface and make a procedure that the button uses. The button only worked once you completed both of these separate steps. In the remainder of this tutorial, you will often have to complete two or more similar steps to add another feature to the model. If something doesn't appear to work after

you completed what you thought is the final step for that new feature, continue to read ahead to see if there is still more to do. After reading ahead for a couple of paragraphs, you should then go back over the directions to see if there is any step you might have missed.

Making the go button

Now make a button called "go". Follow the same steps you used to make the setup button, except:

- For Commands enter `go` instead of `setup`.
- Check the "forever" checkbox in the edit dialog.



The "forever" checkbox makes the button stay down once pressed, so its commands run over and over again, not just once.

- Then add a go procedure to the Procedures tab:

```
to go
  move-turtles
end
```

But what is `move-turtles`? Is it a primitive (in other words, built in to NetLogo), like `clear-all` is? No, it's another procedure that you're about to add. So far, you have introduced two procedures that you added yourself: `setup` and `go`.

- Add the `move-turtles` procedure after the goprocedure:

```
to go
  move-turtles
end

to move-turtles
  ask turtles [
    right random 360
    forward 1
  ]
end
```

Note there are no spaces around the dash in `move-turtles`. In Tutorial #2 we used `red - 2`, with spaces, in order to subtract two numbers, but here we want `move-turtles`, without spaces. The "-" combines "move" and "turtles" into a single name.

Here is what each command in the `move-turtles` procedure does:

- `ask turtles [ ... ]` says that each turtle should run the commands in the brackets.
- `right random 360` is another command that uses a reporter. First, each turtle picks a random whole number between 0 and 359. (`random` doesn't include the number you give it as a possible result.) Then the turtle turns right this number of degrees.
- `forward 1` makes the turtle move forward one step.

Why couldn't we have just written all of these commands in `go` instead of in a separate procedure? We could have, but during the course of building your project, it's likely that you'll add many other parts. We'd like to keep `go` as simple as possible, so that it is easy to understand. Eventually, it will include many other things you want to have happen as the model runs, such as calculating something or plotting the results. Each of these things to do will have its own procedure and each procedure will have its own unique name.

The 'go' button you made in the Interface tab is a forever button, meaning that it will continually run its commands until you shut it off (by clicking on it again). After you have pressed 'setup' once, to create the turtles, press the 'go' button. Watch what happens. Turn it off, and you'll see that all the turtles stop in their tracks.

Note that if a turtle moves off the edge of the world, it "wraps", that is, it appears on the other side. (This is the default behavior. It can be changed; see the Topology section of the Programming Guide for more information.)

Experimenting with commands

We suggest you start experimenting with other turtle commands.

Type commands into the Command Center (like `turtles> set color red`), or add commands to `setup`, `go`, or `move-turtles`.

Note that when you enter commands in the Command Center, you must choose `turtles>`, `patches>`, or `observer>` in the popup menu on the left, depending on which agents are going to

run the commands. It's just like using `ask turtles` or `ask patches`, but saves typing. You can also use the tab key to switch agent types, which you might find more convenient than using the menu.

You might try typing `turtles> pen-down` into the Command Center and then pressing the go button.

Also, inside the `move-turtles` procedure you can try changing `right random 360` to `right random 45`.

Play around. It's easy and the results are immediate and visible -- one of NetLogo's many strengths.

When you feel you've done enough experimenting for now, you're ready to continue improving the model you are building.

Patches and variables

Now we've got 100 turtles aimlessly moving around, completely unaware of anything else around them. Let's make things a little more interesting by giving these turtles a nice background against which to move.

- Go back to the `setup` procedure. We can rewrite it as follows:

```
to setup
  clear-all
  setup-patches
  setup-turtles
end
```

- The new definition of `setup` refers to two new procedures. To define `setup-patches`, add this:

```
to setup-patches
  ask patches [ set pcolor green ]
end
```

The `setup-patches` procedure sets the color of every patch to green to start with. (A turtle's color variable is `color`; a patch's is `pcolor`.)

The only part remaining in our new 'setup' that is still undefined is `setup-turtles`.

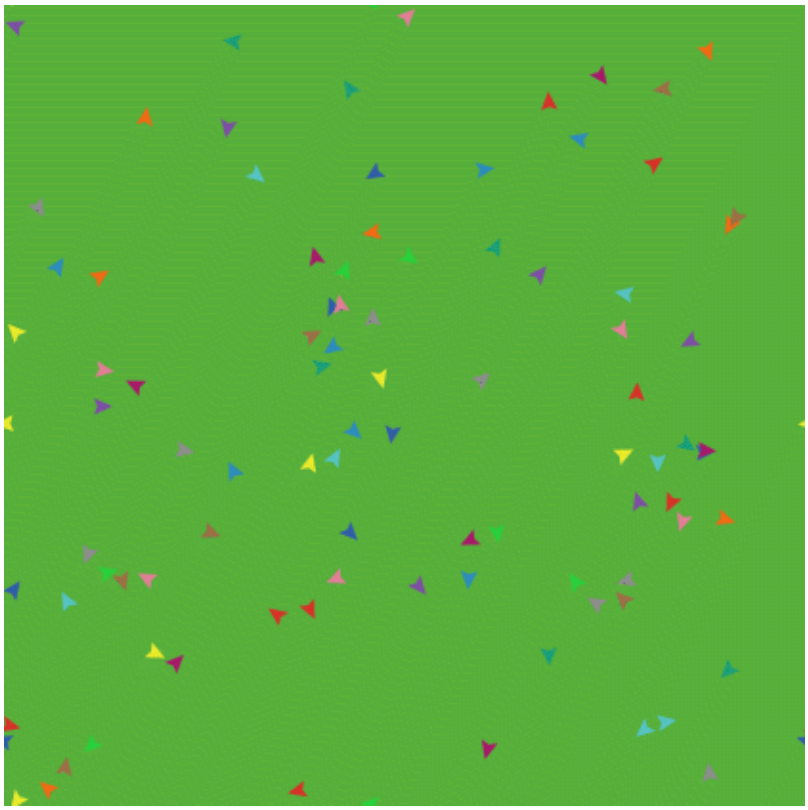
- Add this procedure too:

```
to setup-turtles
  create-turtles 100
  ask turtles [ setxy random-xcor random-ycor ]
end
```

Did you notice that the new `setup-turtles` procedure has most of the same commands as the old `setup` procedure?

- Switch back to the Interface tab.
- Press the setup button.

Voila! A lush NetLogo landscape complete with turtles and green patches appears:



After seeing the new `setup` procedure work a few times, you may find it helpful to read through the procedure definitions again.

Turtle variables

So we have some turtles running around on a landscape, but they aren't doing anything with it. Let's add some interaction between the turtles and the patches.

We'll make the turtles eat "grass" (the green patches), reproduce, and die. The grass will gradually grow back after it is eaten.

We'll need a way of controlling when a turtle reproduces and dies. We'll determine that by keeping track of how much "energy" each turtle has. To do that we need to add a new turtle variable.

You've already seen built in turtle variables like `color`. To make a new turtle variable, we add a `turtles-own` declaration at the top of the Procedures tab, before all the procedures. Call it `energy`:

```
turtles-own [energy]
```

```
to go
  move-turtles
  eat-grass
end
```

Let's use this newly defined variable (`energy`) to allow the turtles to eat.

- Switch to the Procedures tab.
- Rewrite the `go` procedure as follows:

```
to go
  move-turtles
  eat-grass
end
```

- Add a new `eat-grass` procedure:

```
to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
      set energy (energy + 10)
    ]
  ]
end
```

We are using the `if` command for the first time. Look at the code carefully. Each turtle, when it runs these commands, compares the value of the patch color it is on (`pcolor`) to the value for `green`. (A turtle has direct access to the variables of the patch it is standing on.) If the patch color is green, the comparison reports `true`, and only then will the turtle runs the commands inside the brackets (otherwise it skips them). The commands make the turtle change the patch color to black and increase its own energy by 10. The patch turns black to signify that the grass at that spot has been eaten and the turtle is given more energy, from having just eaten the grass.

Next, let's make the movement of turtles use up some of the turtle's energy.

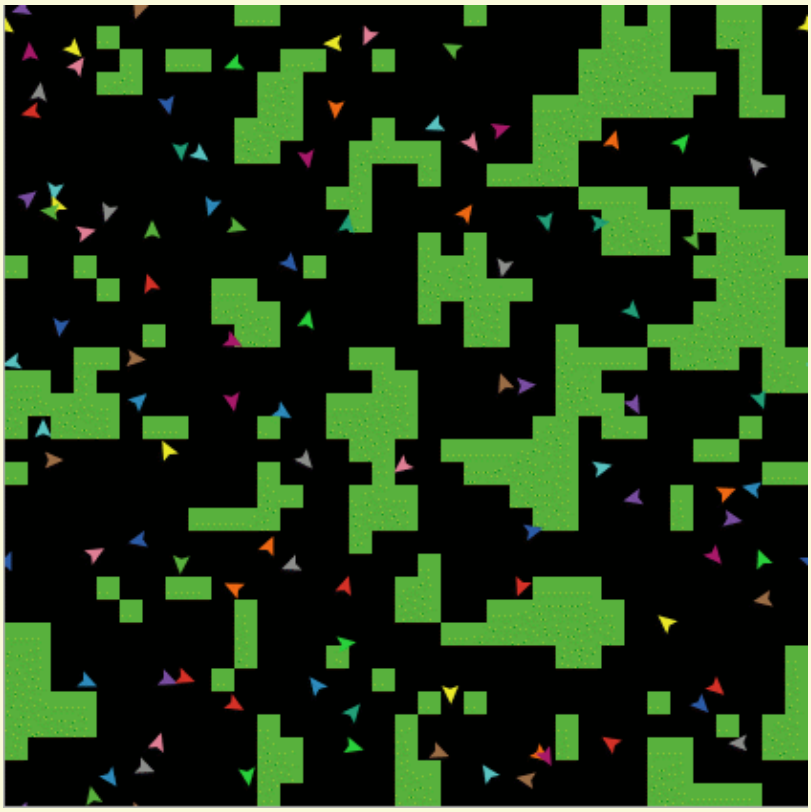
- Rewrite `move-turtles` as follows:

```
to move-turtles
  ask turtles [
    right random 360
    forward 1
    set energy energy - 1
  ]
end
```

As each turtle wanders, it will lose one unit of energy at each step.

- Switch to the Interface tab now and press the setup button and the go button.

You'll see the patches turn black as turtles travel over them.



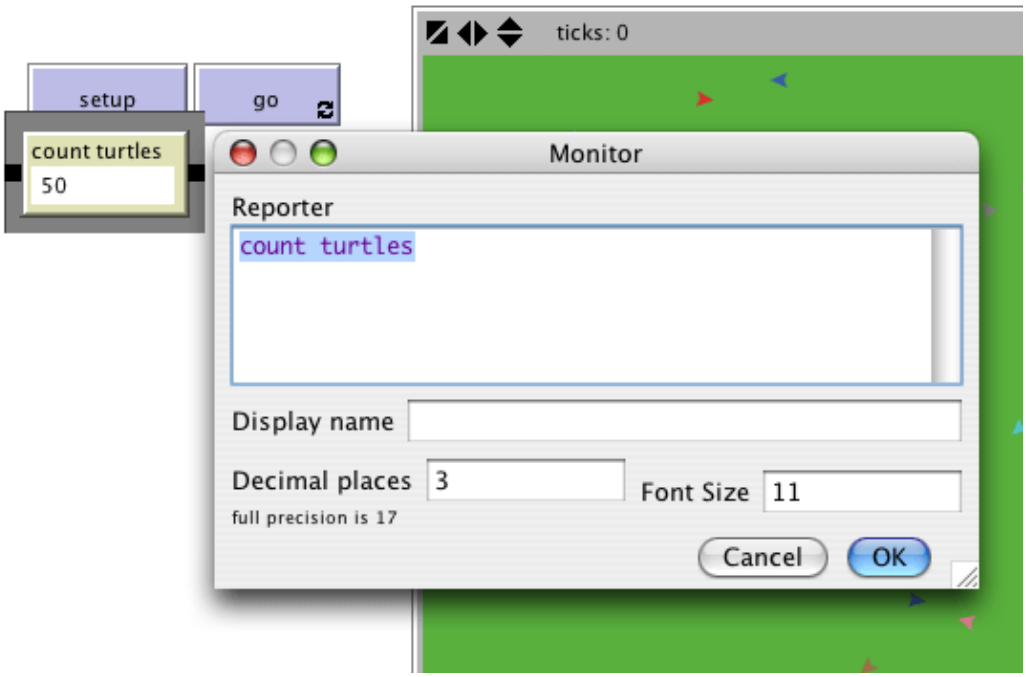
Monitors

Next you will create two monitors in the Interface tab with the Toolbar. (You make them just like buttons and sliders, using the monitor icon on the Toolbar.) Let's make the first monitor now.

- Create a monitor, using the monitor icon on the Toolbar and click on an open spot in the Interface.

A dialog box will appear.

- In the dialog box type: `count turtles` (see image below).
- Press the OK button to close the dialog box.



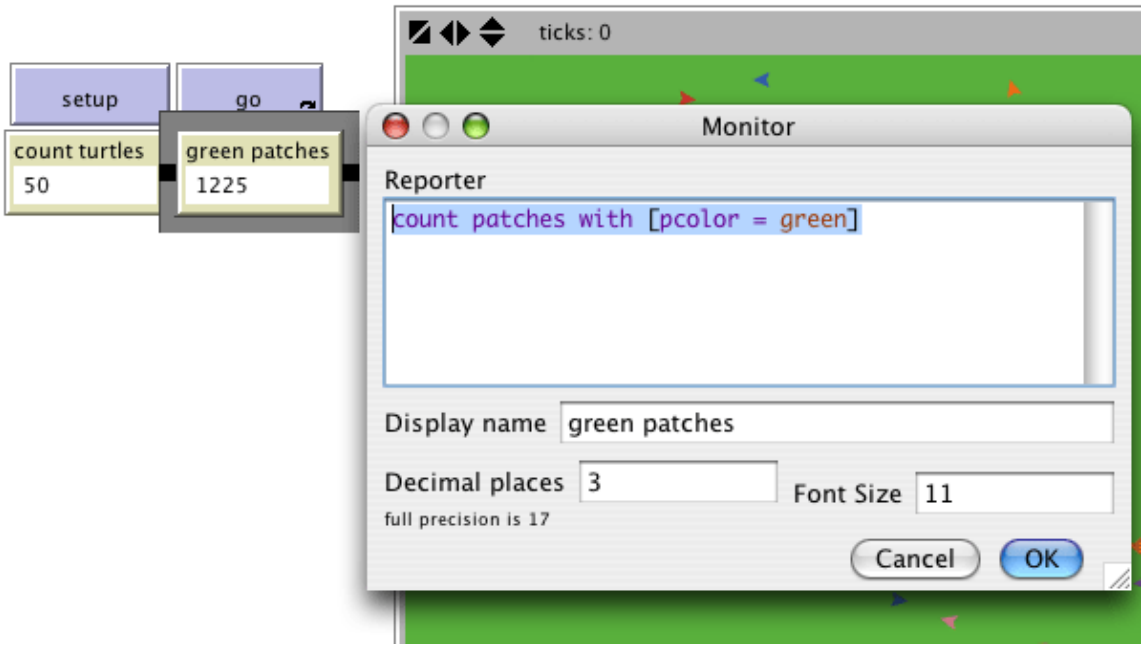
`turtles` is an "agentset", the set of all turtles. `count` tells us how many agents are in that set.

Let's make the second monitor now:

- Create a monitor, using the monitor icon on the Toolbar and click on an open spot in the Interface.

A dialog box will appear.

- In the Reporter section of the dialog box type: `count patches with [pcolor = green]` (see image below).
- In the Display name section of the dialog box type: `green patches`
- Press the OK button to close the dialog box.



Here we're using `count` again to see how many agents are in an agentset. `patches` is the set of all the patches, but we don't just want to know how many patches there are total, we want to know how many of them are green. That's what `with` does; it makes a smaller agentset of just those agents for whom the condition in the brackets is true. The condition is `pcolor = green`, so that gives us just the green patches.

Now we have two monitors that will report how many turtles and green patches we have, to help us track what's going on in our model. As the model runs, the numbers in the monitors will automatically change.

- Use the setup and go buttons and watch the numbers in the monitors change.

Switches and labels

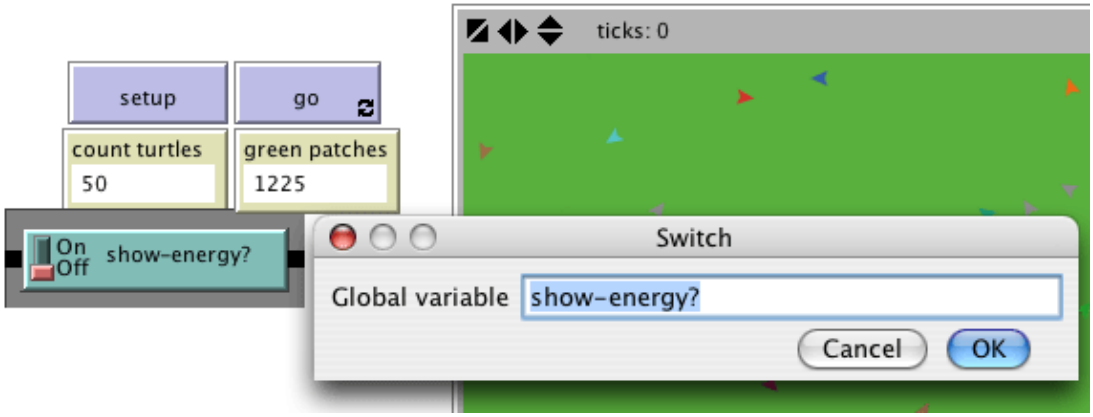
The turtles aren't just turning the patches black; they're also gaining and losing energy. As the model runs, try using a turtle monitor to watch one turtle's energy go up and down.

It would be nicer if we could see every turtle's energy all the time. We will now do exactly that, and add a switch so we can turn the extra visual information on and off.

- To create a switch, click on the switch icon on the Toolbar (in the Interface tab) and click on an open spot in the Interface.

A dialog box will appear.

- In the Global variable section of the dialog box type: `show-energy?` Don't forget to include the question mark in the name. (See image below.)



- Now go back to the 'go' procedure using the Procedures tab with the Toolbar.
- Rewrite the `eat-grass` procedure as follows:

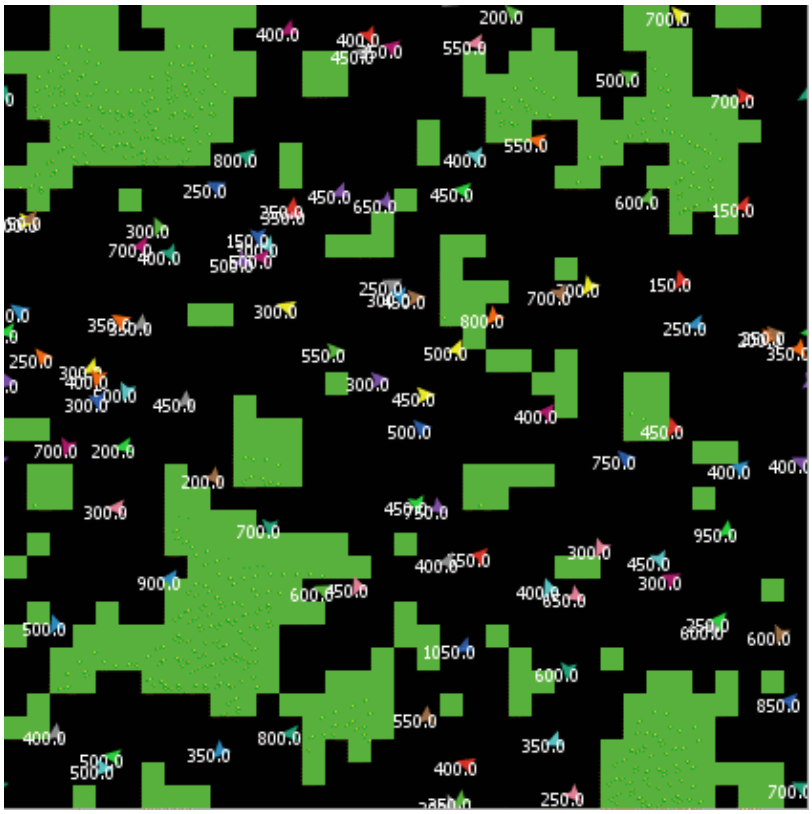
```
to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
      set energy (energy + 10)
    ]
  ifelse show-energy?
    [ set label energy ]
    [ set label "" ]
  ]
end
```

The `eat-grass` procedure introduces the `ifelse` command. Look at the code carefully. Each turtle, when it runs these new commands, checks the value of `show-energy?` (determined by the switch). If the switch is on, comparison is true and the turtle will run the commands inside the first set of brackets. In this case, it assigns the value for the energy to the label of the turtle. If the comparison is false (the switch is off) then the turtle runs the commands inside the second set of brackets. In this case, it removes the text labels (by setting the label of the turtle to be nothing).

(In NetLogo, a piece of text is called a "string". A string is a sequence of letters and other characters, written between double quotes. Here we have two double quotes right next to each other, with nothing in between them. That's an empty string. If a turtle's label is an empty string, no text is attached to the turtle.)

- Test this in the Interface tab, by running the model (using the setup and go buttons) switching the `show-energy?` switch back and forth.

When the switch is on, you'll see the energy of each turtle go up each time it eats grass. You'll also see its energy going down whenever it moves.



More procedures

Now our turtles are eating; let's make them reproduce and die, too. Let's also make the grass grow back. We'll add all three of these of these behaviors now, by making three separate procedures, one for each behavior.

- Go to the Procedures tab.
- Rewrite the `go` procedure as follows:

```
to go
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
end
```

- Add the procedures for `reproduce`, `check-death`, and `regrow-grass` as shown below:

```
to reproduce
  ask turtles [
    if energy > 50 [
      set energy energy - 50
```

```
      hatch 1 [ set energy 50 ]
    ]
  ]
end

to check-death
  ask turtles [
    if energy <= 0 [ die ]
  ]
end

to regrow-grass
  ask patches [
    if random 100 < 3 [ set pcolor green ]
  ]
end
```

Each of these procedures uses the `if` command. Each turtle, when it runs `reproduce`, checks the value of the turtle's `energy` variable. If it is greater than 50, then the turtle runs the commands inside the first set of brackets. In this case, it decreases the turtle's energy by 50, then 'hatches' a new turtle with an energy of 50. The `hatch` command is a NetLogo primitive which looks like this: `hatch` *number* [*commands*]. This turtle creates *number* new turtles, each identical to its parent, and asks the new turtle(s) that have been hatched to run *commands*. You can use the commands to give the new turtles different colors, headings, or whatever. In our case we run one command. We set the energy for the newly hatched turtle to be 50.

When each turtle runs `check-death` it will check to see if its energy is less or equal to 0. If this is true, then the turtle is told to `die` (die is a NetLogo primitive).

When each patch runs `regrow-grass` it will check to see if a random integer from 0 to 99 is less than 3. If so, the patch color is set to green. This will happen 3% of the time (on average) for each patch, since there are three numbers (0, 1, and 2) out of 100 possible that are less than 3.

- Switch to the Interface tab now and press the setup and go buttons.

You should see some interesting behavior in your model now. Some turtles die off, some new turtles are created (hatched), and some grass grows back. This is exactly what we set out to do.

If you continue to watch your monitors in your model, you will see that the **count turtles** and **green patches** monitors both fluctuate. Is this pattern of fluctuation predictable? Is there a relationship between the variables?

It'd be nice if we had a easier way to track the changes in the model behavior over time. NetLogo allows us to plot data as we go along. That will be our next step.

Plotting

To make plotting work, we'll need to create a plot in the Interface tab, and set some settings in it. Then we'll add one more procedure to the Procedures tab, which will update the plot for us.

Let's do the Procedures tab part first.

- Change `setup` to call the new procedure, `do-plots`, which we're about to add:

```
to setup
  clear-all
  setup-patches
  setup-turtles
  do-plots
end
```

- Also, change `go` to call the `do-plots` procedure:

```
to go
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
  do-plots
end
```

- Now add the new procedure. What we're plotting will be be the number of turtles and the number of green patches versus time. At each time step (a single run through the `go` procedure) these values are added to the plot.

```
to do-plots
  set-current-plot "Totals"
  set-current-plot-pen "turtles"
  plot count turtles
  set-current-plot-pen "grass"
  plot count patches with [pcolor = green]
end
```

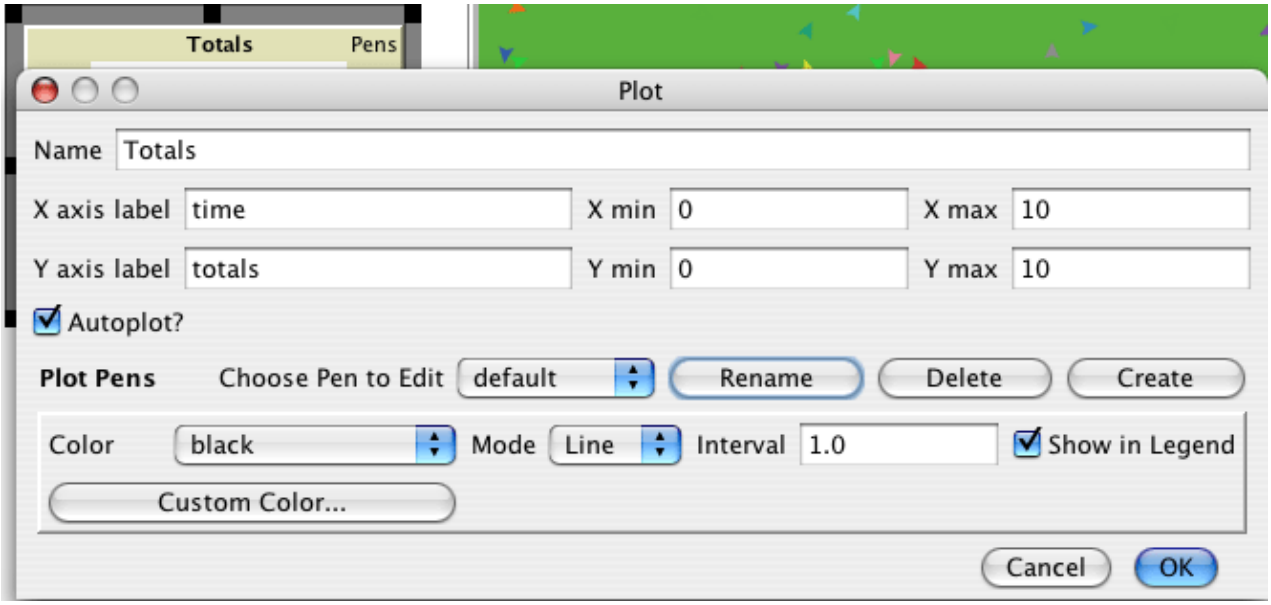
Note that we use the `plot` command to add the next point to a plot. However, before doing that, we need to tell NetLogo two things. First, we need to specify what plot we will be using (since later our model might have more than one plot) and second, we need to specify which pen we want to plot with (we will be using two pens on this plot).

The `plot` command moves the current plot pen to the point that has an X coordinate equal to 1 greater than the previously plotted X coordinate and a Y coordinate equal to the value given in the plot command (in the first case, the number of turtles, and in the second case, the number of green patches). As the pens move they each draw a line.

In order for `set-current-plot "Totals"` to work, you'll have to add a plot to your model in the Interface tab, then edit it so its name is the same name used in the procedures. Even one extra space in the name will throw it off -- it must be exactly the same in both places.

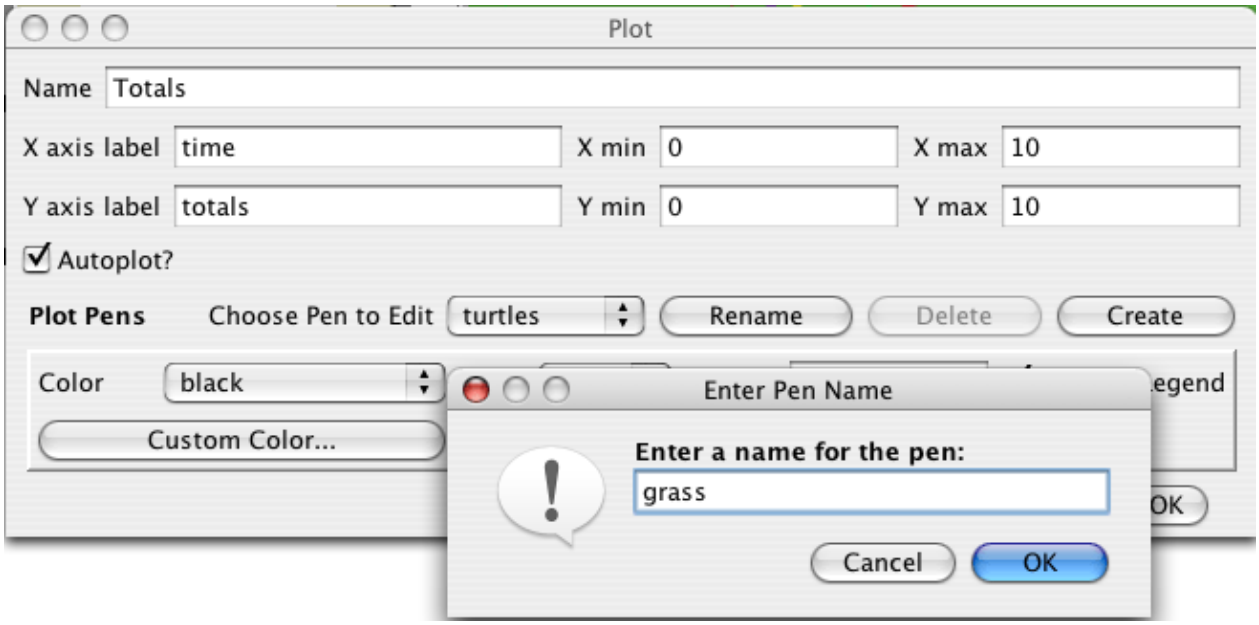
- Create a plot, using the plot icon on the Toolbar and click on an open spot in the Interface.

- Set its Name to "Totals" (see image below)
- Set the X axis label to "time"
- Set the Y axis label to "total"



Next you will need to create two pens.

- With the Plot dialog box still open, press the 'Create' button in the Plot dialog, to create a new pen.
- Enter the name of this pen as "turtles" and press OK in the "Enter Pen Name" dialog. (see image below)
- Press the 'Create' button in the Plot dialog again, to create a second new pen.
- Enter the name of this pen as "grass" and press OK in the "Enter Pen Name" dialog. (see image below)
- Select the color for this pen and change it to green.
- Select OK in the Plot dialog box.

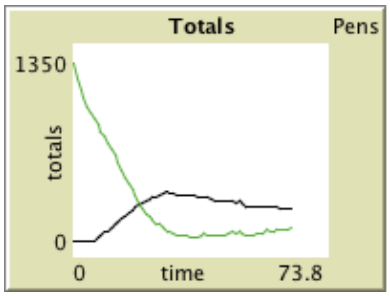


Note that when you create the plot you can also set the minimum and maximum values on the X and Y axes. You'll want to leave the "Autoplot?" checkbox checked, so that if anything you plot exceeds the minimum and maximum values for the axes, the axes will automatically grow so you can see all the data.

- Setup and run the model again.

You can now watch the plot being drawn as the model is running. Your plot should have the general shape of the one below, though your plot might not look exactly the same.

Remember that we left "Autoplot?" on. This allows the plot to readjust itself when it runs out of room.



If you forget which pen is which, click on the Pens label on the top right corner of the plot. You might try running the model several times to see what aspects of the plot are the same and which are different.

Tick counter

To make comparisons between plots from one model run and another, it is often useful to do the comparison for the same length of model run. Learning how to stop or start an action at a specific time can help make this happen by stopping the model at the same point each model run. Keeping track of how many times the `go` procedure is run is a useful way to cue these actions.

To keep track of this, we will use NetLogo's built−in tick counter.

- Change the `go` procedure:

```
to go
  if ticks >= 500 [ stop ]
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
  tick
  do-plots
end
```

- Now setup and run the model.

The graph and model won't keep running forever. They should stop automatically when the tick counter in the Interface tab's toolbar reaches 500.

The `tick` command advances the tick counter by 1. `ticks` is a reporter which reports the current value of the tick counter. `clear-all` takes care of resetting the tick counter to 0 when a new run starts.

Note that we put `tick` before `do-plots`. That's so if we write plotting code that uses the value of the tick counter, it will see the new value, not the old value. (In this tutorial we won't actually write any code like that, but nonetheless, it is generally good practice to call `tick` after your agents have done their actions but before you plot.)

Now that your model uses ticks, you'll probably want to use the menu at the top of the Interface tab to change from "continuous" updates to "tick−based" updates. That means that NetLogo will only update (that is, redraw) the view (that is, the display area where you see your agents) between ticks, never in the middle of a tick. This makes your model run faster and ensures a consistent appearance (since the updates will happen at consistent times). See the Programming Guide for a fuller discussion of view updates.

Some more details

First, instead of always using 100 turtles, you can have a variable number of turtles.

- Make a slider variable called 'number', using the monitor icon on the Toolbar and click on an open spot in the Interface. Try changing the minimum and maximum values in the slider.
- Then inside of `setup-turtles`, instead of `create-turtles 100` you can type:

```
to setup-turtles
  create-turtles number
  ask turtles [ setxy random-xcor random-ycor ]
end
```

Test this change and compare how having more or fewer turtles initially affect the plots over time.

Second, wouldn't it be nice to adjust the energy the turtles gain and lose as they eat grass and reproduce?

- Make a slider called `energy-from-grass`.
- Make another slider called `birth-energy`.
- Then, inside of `eat-grass`, make this change:

```
to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
      set energy (energy + energy-from-grass)
    ]
    ifelse show-energy?
      [ set label energy ]
      [ set label "" ]
  ]
end
```

- And, inside of `reproduce`, make this change:

```
to reproduce
  ask turtles [
    if energy > birth-energy [
      set energy energy - birth-energy
      hatch 1 [ set energy birth-energy ]
    ]
  ]
end
```

Finally, what other slider could you add to vary how often grass grows back? Are there rules you can add to the movement of the turtles or to the newly hatched turtles that happen only at certain times? Try writing them.

What's next?

So now you have a simple model of an ecosystem. Patches grow grass; turtles wander, eat the grass, reproduce, and die. You have created an interface containing buttons, sliders, switches,

monitors, and plots. You've even written a series of procedures to give the turtles something to do.

That's where this tutorial leaves off.

If you'd like to look at some more documentation about NetLogo, the Interface Guide section of the manual walks you through every element of the NetLogo interface in order and explains its function. For a detailed description and specifics about writing procedures, refer to the Programming Guide. All of the primitives are listed and described in the the NetLogo Dictionary.

Also, you can continue experimenting with and expanding this model if you'd like, experimenting with different variables and behaviors for the agents.

Alternatively, you may want to revisit the first model in the tutorial, Wolf Sheep Predation. This is the model you used in `Tutorial #1`. In the Wolf Sheep Predation model, you saw sheep move around, consume resources that are replenished occasionally (grass), reproduce under certain conditions, and die if they ran out of resources. But that model had another type of creature moving around −− wolves. The addition of wolves requires some additional procedures and some new primitives. Wolves and sheep are two different "breeds" of turtle. To see how to use breeds, study Wolf Sheep Predation.

Alternatively, you can look at other models (including the many models in the Code Examples section of the Models Library) or even go ahead and build your own model. You don't even have to model anything. It can be interesting just to watch patches and turtles forming patterns, to try to create a game to play, or whatever.

Hopefully you have learned some things, both in terms of the NetLogo language and about how to go about building a model. The entire set of procedures that was created above is shown below.

Appendix: Complete code

The complete model is also available in NetLogo's Models Library, in the Code Examples section. It's called "Tutorial 3".

Notice that this listing is full of "comments", which begin with semicolons. Comments let you mix an explanation the code right in with the code itself. You might use comments to help others understand your model, or you might use them as notes to yourself.

In the Procedures tab, comments are gray, so your eyes can pick them out easily.

```
turtles-own [energy] ;; for keeping track of when the turtle is ready
                     ;; to reproduce and when it will die

to setup
  clear-all
  setup-patches
  setup-turtles
  do-plots
end

to setup-patches
  ask patches [ set pcolor green ]
end
```

```
to setup-turtles
  create-turtles number    ;; uses the value of the number slider to create turtles
  ask turtles [ setxy random-xcor random-ycor ]
end

to go
  if ticks >= 500 [ stop ]  ;; stop after 500 ticks
  move-turtles
  eat-grass
  reproduce
  check-death
  regrow-grass
  tick                    ;; increase the tick counter by 1 each time through
  do-plots
end

to move-turtles
  ask turtles [
    right random 360
    forward 1
    set energy energy - 1  ;; when the turtle moves it looses one unit of energy
  ]
end

to eat-grass
  ask turtles [
    if pcolor = green [
      set pcolor black
           ;; the value of energy-from-grass slider is added to energy
      set energy (energy + energy-from-grass)
    ]
  ifelse show-energy?
    [ set label energy ] ;; the label is set to be the value of the energy
    [ set label "" ]     ;; the label is set to an empty text value
  ]
end

to reproduce
  ask turtles [
    if energy > birth-energy [
    set energy energy - birth-energy  ;; take away birth-energy to give birth
    hatch 1 [ set energy birth-energy ] ;; give this birth-energy to the offspring
    ]
  ]
end

to check-death
  ask turtles [
    if energy <= 0 [ die ] ;; removes the turtle if it has no energy left
  ]
end

to regrow-grass
  ask patches [ ;; 3 out of 100 times, the patch color is set to green
    if random 100 < 3 [ set pcolor green ]
  ]
end

to do-plots
  set-current-plot "Totals" ;; which plot we want to use next
  set-current-plot-pen "turtles" ;; which pen we want to use next
  plot count turtles ;; what will be plotted by the current pen
```

```
  set-current-plot-pen "grass" ;; which pen we want to use next
  plot count patches with [pcolor = green] ;; what will be plotted by the current pen
end
```

Interface Guide

This section of the manual walks you through every element of the NetLogo interface in order and explains its function.

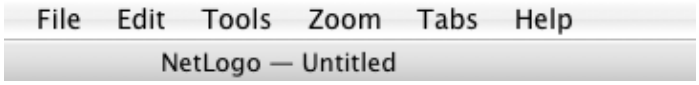
In NetLogo, you have the choice of viewing models found in the Models Library, adding to existing models, or creating your own models. The NetLogo interface was designed to meet all these needs.

The interface can be divided into two main parts: NetLogo menus, and the main NetLogo window. The main window is divided into tabs.

- Menus
- Tabs
- Interface Tab
  - Working with Interface Elements
  - The 2D and 3D Views
  - Command Center
  - Plots
- Information Tab
- Procedures Tab
- Includes Menu

Menus

On Macs, if you are running the NetLogo application, the menubar is located at the top of the screen. On other platforms, the menubar is found at the top of the NetLogo window.



The functions available from the menus in the menubar are listed in the following chart.

Chart: NetLogo Menus

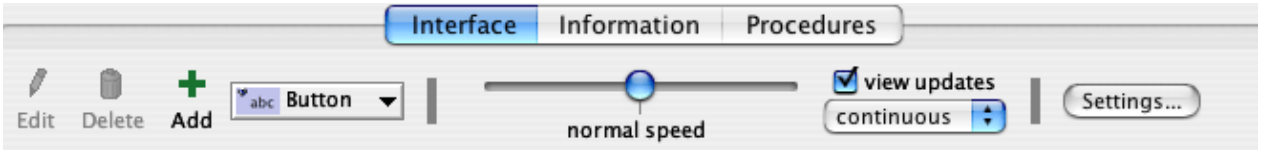
File		
	New	Starts a new model.
	Open	Opens any NetLogo model on your computer.
	Models Library	A collection of demonstration models.
	Save	Save the current model.
	Save As	Save the current model using a different name.
	Save As Applet	Used to save a web page in HTML format that has your model embedded in it as a Java "applet".
	Print	Sends the contents of the currently showing tab to your printer.
	Export World	Saves all variables, the current state of all turtles and patches, the drawing , the plots, the output area and the random state information to a file.
	Export Plot	Saves the data in a plot to a file.
	Export All Plots	Saves the data in all the plots to a file.

	Export View	Save a picture of the current view (2D or 3D) to a file (in PNG format).
	Export Interface	Save a picture of the current Interface tab. (in PNG format)
	Export Output	Save the contents of the output area or the output section of the command center to a file.
	Import World	Load a file that was saved by Export World.
	Import Patch Colors	Load an image into the patches; see the import−pcolors command.
	Import Patch Colors RGB	Load an image into the patches using RGB colors; see the import−pcolors−rgb command.
	Import Drawing	Load an image into the drawing, see the import−drawing command.
	Import HubNet Client Interface	Load the interface from another model into the HubNet Client Editor.
	Quit	Exits NetLogo. (On Macs, this item is on the NetLogo menu instead.)
Edit		
	Cut	Cuts out or removes the selected text and temporarily saves it to the clipboard.
	Copy	Copies the selected text.
	Paste	Places the clipboard text where cursor is currently located.
	Delete	Deletes selected text.
	Undo	Undo last text editing action you performed.
	Redo	Redo last undo action you performed.
	Select All	Select all the text in the active window.
	Find	Finds a word or sequence of characters within the Information or Procedures tabs.
	Find Next	Find the next occurrence of the word or sequence you last used Find with.
	Shift Left / Shift Right	Used in the Procedures tab to change the indentation level of code.
	Comment / Uncomment	Used in the Procedures tab to add or remove semicolons from code (semicolons are used in NetLogo code to indicate comments).
	Snap To Grid	When enabled new widgets stay on a 5 pixel grid so it is easier to line them up. (Note: this feature is disabled when zoomed in or out.)
Tools		
	Halt	Stops all running code, including buttons and the command center. (Warning: since the code is interrupted in the middle of whatever it was doing, you may get unexpected results if you try to continue running the model without first pressing "setup" to start the model run over.)
	Globals Monitor	Displays the values of all global variables.
	Turtle Monitor	Displays the values of all of the variables in a particular turtle. You can can also edit the values of the turtle's variables and issue commands to the turtle. (You can also open a turtle monitor via the View; see the View section below.)
	Patch Monitor	Displays the values of all of the variables in a particular patch. You can can also edit the values of the patch's variables and issue commands to the patch. (You can also open a patch monitor via the View; see the View section below.)

	Link Monitor	Displays the values of all of the variables in a particular link. You can can also edit the values of the link's variables and issue commands to the link. (You can also open a link monitor via the View; see the View section below.)
	Hide/Show Command Center	Makes the command center visible or invisible. (Note that the command center can also be shown or hidden, or resized, with the mouse.)
	3D View	Opens the 3D view. See the View section for more information.
	Color Swatches	Opens the Color Swatches. See the Color Section of the Programming Guide for details.
	Turtle Shapes Editor	Draw turtle shapes. See the Shapes Editor Guide for more information.
	Link Shapes Editor	Draw link shapes. See the Shapes Editor Guide for more information.
	BehaviorSpace	Runs the model over and over with different settings. See the BehaviorSpace Guide for more information.
	System Dynamics Modeler	Opens the System Dynamics Modeler. See the System Dynamics Modeler Guide for more details.
	HubNet Client Editor	Opens the HubNet Client Editor. See the HubNet Authoring Guide for more details.
	HubNet Control Center	Disabled if no HubNet activity is open. See the HubNet Guide for more information.
Zoom		
	Larger	Increase the overall screen size of the model. Useful on large monitors or when using a projector in front of a group.
	Normal Size	Reset the screen size of the model to the normal size.
	Smaller	Decrease the overall screen size of the model.
Tabs		This menu offers keyboard shortcuts for each of the tabs. (On Macs, it's Command 1 through Command 3. On Windows, it's Control 1 through Control 3.)
Help		
	About NetLogo	Information on the current NetLogo version the user is running. (On Macs, this menu item is on the NetLogo menu instead.)
	Look Up In Dictionary	Opens a browser with the dictionary entry for the selected command or reporter.
	NetLogo User Manual	Opens this manual in a web browser.
	NetLogo Dictionary	Opens the NetLogo Dictionary in a web browser.

Tabs

At the top of NetLogo's main window are three tabs labeled "Interface", "Information" and "Procedures" . Only one tab at a time can be visible, but you can switch between them by clicking on the tabs at the top of the window.



Right below the row of tabs is a toolbar containing a row of buttons. The buttons available vary from tab to tab.

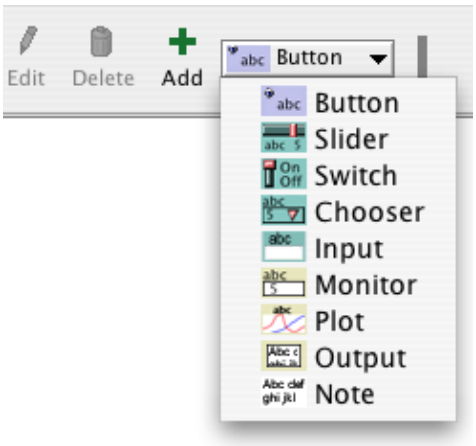
Interface Tab

The Interface tab is where you watch your model run. It also has tools you can use to inspect and alter what's going on inside the model.

When you first open NetLogo, the Interface tab is empty except for the View, where the turtles and patches appear, and the Command Center, which allows you to issue NetLogo commands.

Working with Interface Elements

The toolbar on the Interface tab contains buttons that let you edit, delete, and create items in the Interface tab and a menu that lets you select different interface items (such as buttons and sliders).



The buttons in the toolbar are described below.

Adding: To add an interface element, select the element from the the drop down menu. Note that the Add button becomes pressed. Then click on the white area below the toolbar. (If the menu is already showing the right type, you can just press the Add button instead of using the menu again.)

Selecting: To select an interface element, drag a rectangle around it with your mouse. A gray border will appear around the element to indicate that it is selected.

Selecting Multiple Items: You can select multiple interface elements at the same time by including them in the rectangle you drag. If multiple elements are selected, one of them is the "key" item, which means that if you use the "Edit" or "Delete" buttons on the Interface Toolbar, only the key item is affected. The key item is indicated by a darker gray border than the other items.

Unselecting: To unselect all interface elements, click the mouse on the white background of the Interface tab. To unselect an individual element, control−click (Macintosh) or right−click (other systems) the element and choose "Unselect" from the popup menu.

Editing: To change the characteristics of an interface element, select the element, then press the "Edit" button on the Interface Toolbar. You may also double click the element once it is selected. A

third way to edit an element is to control−click (Macintosh) or right−click (other systems) it and choose "Edit" from the popup menu. If you use this last method, it is not necessary to select the element first.

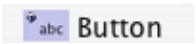
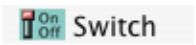
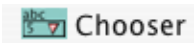
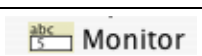
Moving: Select the interface element, then drag it with your mouse to its new location. If you hold down the shift key while dragging, the element will move only straight up and down or straight left and right.

Resizing: Select the interface element, then drag the black "handles" in the selection border.

Deleting: Select the element or elements you want to delete, then press the "Delete" button on the Interface Toolbar. You may also delete an element by control−clicking (Macintosh) or right−clicking (other systems) it and choosing "Delete" from the popup menu. If you use this latter method, it is not necessary to select the element first.

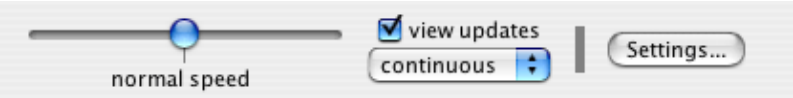
To learn more about the different kinds of interface elements, refer to the chart below.

Chart: Interface Toolbar

Icon & Name	Description
	Buttons can be either *once−only* buttons or *forever* buttons. When you click on a once button, it executes its instructions once. The forever button executes the instructions over and over, until you click on the button again to stop the action. If you have assigned an action key to the button, pressing the corresponding keyboard key will act just like a button press when the button is in focus. Buttons with action keys have a letter in the upper right corner of the button to show what the action key is. If the input cursor is in another interface element such as the Command Center, pressing the action key won't trigger the button. The letter in the upper right hand corner of the button will be dimmed in this situation. To enable action keys, click in the white background of the Interface tab.
	Sliders are global variables, which are accessible by all agents. They are used in models as a quick way to change a variable without having to recode the procedure every time. Instead, the user moves the slider to a value and observes what happens in the model.
	Switches are a visual representation for a true/false variable. The user is asked to set the variable to either on (true) or off (false) by flipping the switch.
	Choosers let the user choose a value for a global variable from a list of choices, presented in a drop down menu.
	Input Boxes are global variables that contain strings or numbers. The model author chooses what types of values the user can enter. Input boxes can be set to check the syntax of a string for commands or reporters. Number input boxes read any type of constant number expression which allows a more open way to express numbers than a slider. Color input boxes offer a NetLogo color chooser to the user.
	Monitors display the value of any expression. The expression could be a variable, a complex expression, or a call to a reporter. Monitors automatically

	update several times per second.
Plot	Plots are real−time graphs of data the model is generating.
Output	The output area is a scrolling area of text which can be used to create a log of activity in the model. A model may only have one output area.
Note	Notes lets you add informative text labels to the Interface tab. The contents of notes do not change as the model runs.

The other controls in the Interface Toolbar allow you to control the view updates and various other model properties.



- The slider lets you control how fast the model runs −− this is valuable since some models run so fast that it's hard to see what's going on. You can also fast forward the model by moving the slider to the left and slowing down the frequency of view updates.
- The view updates check box controls whether view updates happen at all.
- The update mode menu allows you to switch between continuous and tick−based update modes.
- The Settings button allows you to edit various model properties.

"Continuous updates means that NetLogo updates (that is, redraws) the view many times a second, regardless of what is going on in the model. "Tick−based" updates means that the view only updates when the tick counter advances. (For a fuller discussion of view updates, see the Programming Guide.)

The 2D and 3D Views

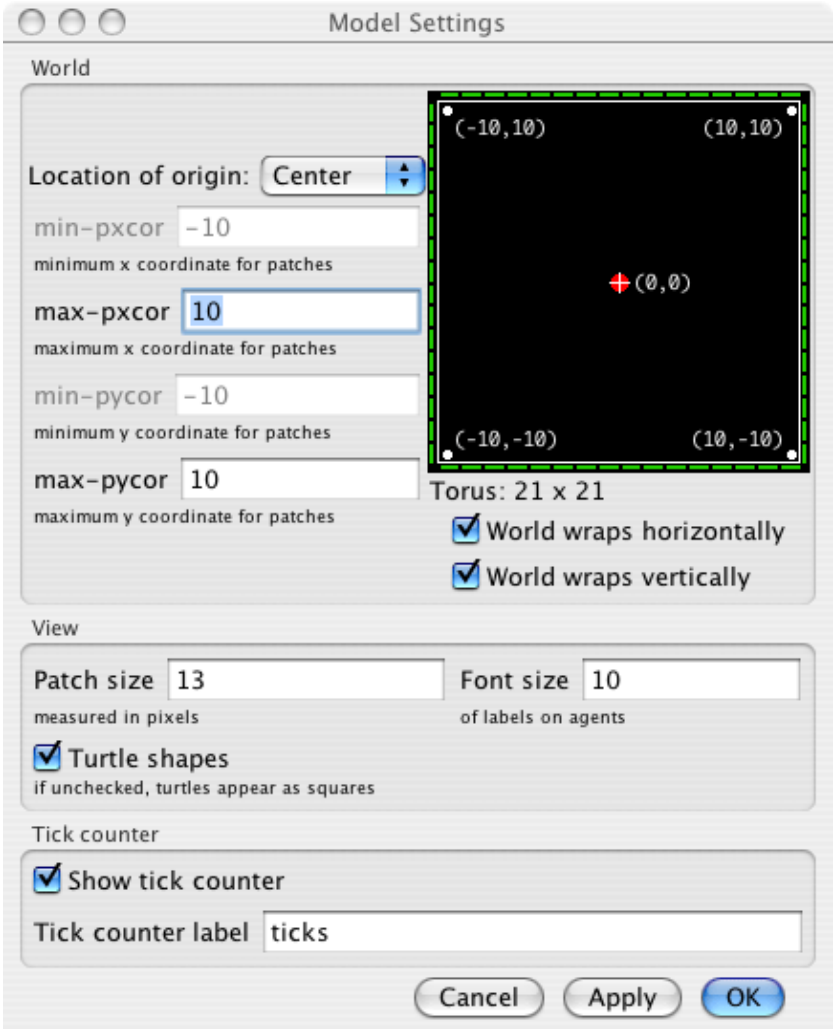
The large black square in the Interface tab is the 2D view. It's a visual representation of the NetLogo world of turtles and patches. Initially it's all black because the patches are black and there are no turtles yet. You can open the 3D View, another visual representation of the world, by clicking on the "3D" button in the View Control Strip.

The three sets of black arrows in the upper left let you change the size of the world. When the origin is centered the world will grow in increments of two, adding one to the maximum and subtracting one from the minimum. If one of the edges is set to 0 the world will grow by one in the other direction to keep the origin along the edge. If the origin is at a custom location the black arrows will be disabled.

There are a number of settings associated with the Views. There are a few ways of changing the settings: by using the control strip along the top edge of the View, or by editing the 2D View, as described in the "Working With Interface Elements" section above, or pressing the "Settings..." button in the toolbar.

Notice that the control strip in the 3D View combines the ticks counter from the 2D view control strip and the controls from the right portion of the interface toolbar.

Here are the settings for the View (accessible by editing the View, or by pressing the "Settings..." button in the Interface Toolbar):



Notice that the settings are broken up into three groups. There are world, view, and ticks counter settings. World settings affect the properties of the world that the turtles live in (changing them may require resetting the world). View and tick counter settings only affect the appearance, changing them will not affect the outcome of the model.

The world settings allow you to define the boundaries and topology of the world. At the top of the left side of the world panel you can choose a location for the origin of the world either "Center", "Corner", "Edge", or "Custom". By default the world has a center configuration where (0,0) is at the center of the world and the user defines the number of patches from the center to the right and left boundaries and the number of patches from the center to the top and bottom boundaries. For Example: If you set Max−Pxcor = 10 Min−Pxcor will automatically be set to −10 thus there are 10 patches to the left of the origin and 10 patches to the right of patch 0 0.

A Corner configuration allows the user to define the location of the origin as one of the corners of the world, upper left, upper right, lower left, or lower right. Then you define the far boundary in the x and y directions. For example if you choose to put the origin in the lower left corner of the world you define the right and top (positive) boundaries.

Edge mode allows you to place the origin along one of the edges (x or y) then define the far boundary in that direction and both boundaries in the other. For example if you select edge mode along the bottom of the world, you must also define the top boundary, as well as the left and the right.

Finally, Custom mode allows the user to place the origin at any location in the world, though patch 0 0 must still exist in the world.

As you change the settings you will notice that the changes you make are reflected in the preview on the right side of the panel which shows the origin and the boundaries. The width and height of the world are displayed below the preview.

Also below the preview there are two checkboxes, the world wrap settings. These allow you to control the topology of the world. Notice when you click the check boxes the preview indicates which directions allow wrapping, and the name of the topology is displayed next to the world dimensions. See the Topology Section of the Programming Guide for more information.

The view settings allow you to customize the look of the view without changing the world. Changing view settings will never force a world reset. To change the size of the 2D View adjust the "Patch Size" setting, measured in pixels. This does not change the number of patches, only how large the patches appear in the 2D View. (Note that the patch size does not affect the 3D View, as you can simply make the 3D View larger by making the window larger.)

The "Turtle Shapes" checkbox lets you turn turtle "shapes" on and off. If shapes are off, turtles appear as colored squares, instead of having special shapes. The squares are less work for the computer to draw, so turning shapes off makes models run faster.

The "Smooth edges" checkbox controls the use of anti−aliasing in the 3D view only and only appears when editing from the 3D view. It will make the lines appear less jagged but it will slow down the model.

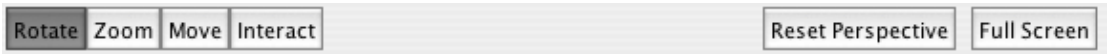
Tick counter settings control the appearance of the tick counter which is visible (or not) in the view control strip.

Turtle, patch and link monitors are easily available through the View, just control−click (Macintosh) or right−click (other systems) on the turtle or patch you want to inspect, and choose "inspect turtle ..." or "inspect patch ..." from the popup menu. You can also watch, follow or ride a turtle by selecting the appropriate item in the turtle sub−menu. (Turtle, patch and link monitors can also be opened from the Tools menu or by using the `inspect` command.)

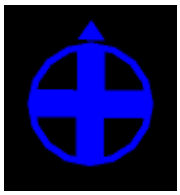
Some NetLogo models let you interact with the turtles and patches with your mouse by clicking and dragging in the View.

Manipulating the 3D View

At the bottom of the window there are buttons to move the observer, or change the perspective from which you are looking at the world.



A blue cross appears at the current focus point as you are adjusting these settings. The little blue triangle will always point up the positive y−axis, so you can orient yourself in case you get lost. It's easy to do!



To look at the world from a different angle, press the "rotate" button click and drag the mouse up, down, left, or right. The observer will continue to face the same point as before (where the blue cross is) but its position in the relation to the xy−plane will change.

To move closer or farther away from the world or the agent you are watching, following or riding, press the "zoom" button and drag up and down along the 3D View. (Note when you are in follow or ride mode zooming will switch you between ride and follow, since ride is just a special case of follow where the distance at which you are following is 0.)

To change the position of the observer without changing the direction it is facing select the "move" button and drag the mouse up, down, left, and right inside the 3D View while holding down the mouse button.

To allow the mouse position and state to be passed to the model select the "interact" button and it will function just as the mouse does in the 2D view.

To return the observer and focus point to their default positions press the "Reset Perspective" button (or use the `reset-perspective` command) .

Fullscreen Mode

To enter fullscreen mode, press the "Full Screen" button, to exit fullscreen mode, press the Esc key.

Note: Fullscreen mode doesn't work on some computers. It depends on what kind of graphics card you have. See the System Requirements for details.

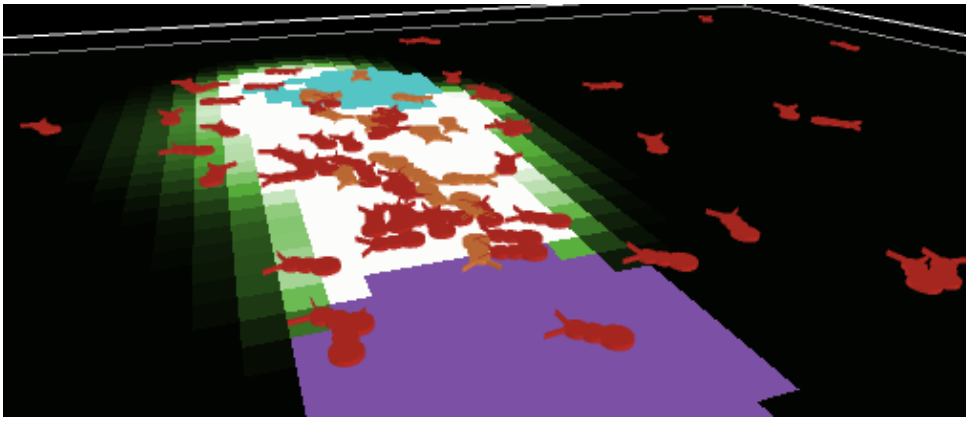
3D Shapes

Some shapes have true 3D counterparts (a 3D circle is actually a sphere) in the 3D view so they are automatically mapped to that shape.

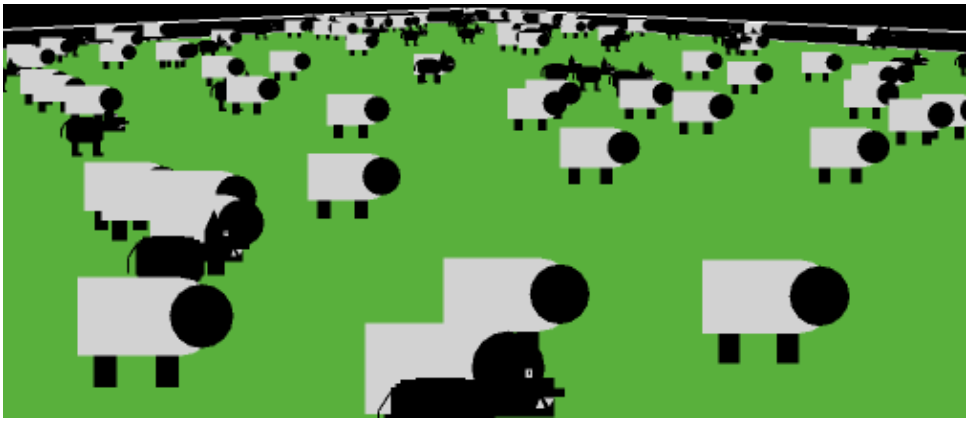
Shape name	3D shape
default	3D turtle shape

circle	sphere
dot	small sphere
square	cube
triangle	cone
line	3D line
cylinder	3D cylinder
line−half	3D line−half
car	3D car

All other shapes are interpreted from their 2D shapes. If a shape is a rotatable shape it is assumed to be a top view and it is extruded as if through a cookie cutter and oriented parallel to the xy−plane, as in Ants.



If a shape is non−rotatable it is assumed to be a side view so it is drawn always facing the observer (and with no thickness), as in Wolf Sheep Predation.

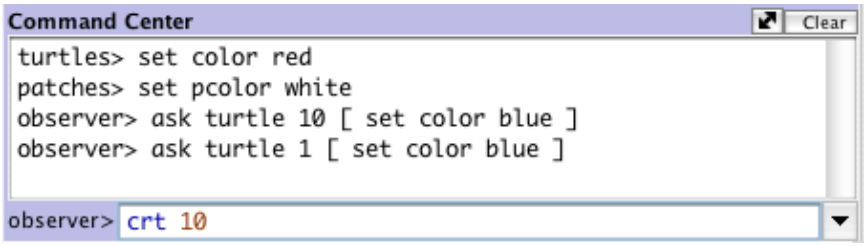


Command Center

The Command Center allows you to issue commands directly, without adding them to the model's procedures. (Commands are instructions you give to the agents in your model.) This is useful for inspecting and manipulating agents on the fly.

(Tutorial #2: Commands is an introduction to using commands in the Command Center.)

Let's take a look at the design of the Command Center.


Command Center
Clear
turtles> set color red
patches> set pcolor white
observer> ask turtle 10 [set color blue]
observer> ask turtle 1 [set color blue]
observer>
crt 10

The smaller box, below the large box, is where you type a command. After typing it press the Return or Enter key to run it.

To the left of where you type is a popup menu that initially says "observer>". You can choose either observer, turtles, or patches, to specify which agents run the command you type.

Tip: a quicker way to change between observer, turtles, and patches is to use the tab key on your keyboard.

Accessing previous commands

After you type a command, it appears in the large scrolling box above the command line. You can use Copy on the Edit menu in this area to copy commands and then paste them elsewhere, such as the Procedures tab.

You can also access previous commands using the history popup menu, which is the small downward pointing triangle to the right of where you type commands. Click on the triangle and a menu of previously typed commands appears, so you can pick one to use again.

Tip: a quicker way to access previous commands is with the up and down arrow keys on your keyboard.

Clearing

To clear the large scrolling area containing previous commands and output, click "clear" in the top right corner.

To clear the history popup menu, choose "Clear History" on that menu.

Arranging

You can hide and show the command center using the Hide Command Center and Show Command Center items on the Tools menu.

To resize the command center, drag the bar that separates it from the model interface. Or, click one of the little arrows on the right end of the bar to make the command center either very big or hidden altogether.

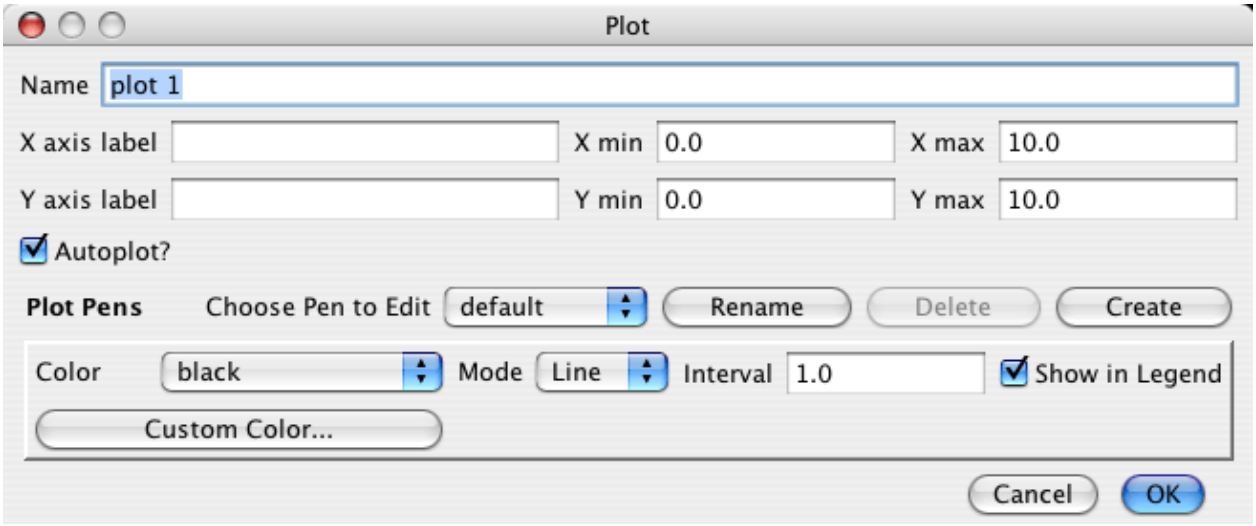
To switch between a vertical command center and a horizontal one, click the button with the double−headed arrow, just to the left of "Clear".

Plots

To show or hide a plot's pens legend, click on the word "Pens" in the upper right corner of a plot.

If you move the mouse over the white area of a plot, the x and y coordinates of the mouse location will appear. (Note that the mouse location might not correspond exactly to any actual data points in the plot. If you need to know the exact coordinates of plotted points, use the Export Plot menu item and inspect the resulting file in another program.)

When you create a plot, as with all widgets, the edit dialog automatically appears.



Many of the fields are fairly self explanatory, the name of the plot, labels for the x and y axes, and ranges for the axes.

If Autoplot? is checked the x and y changes will automatically readjust as points are added to the plot if they are outside the current range.

In the plot pens section of the dialog you can create and customize different pens in this plot. You must always have a least one pen in every plot. You start out with one named "default" you probably want to rename it something that is meaningful in the model.

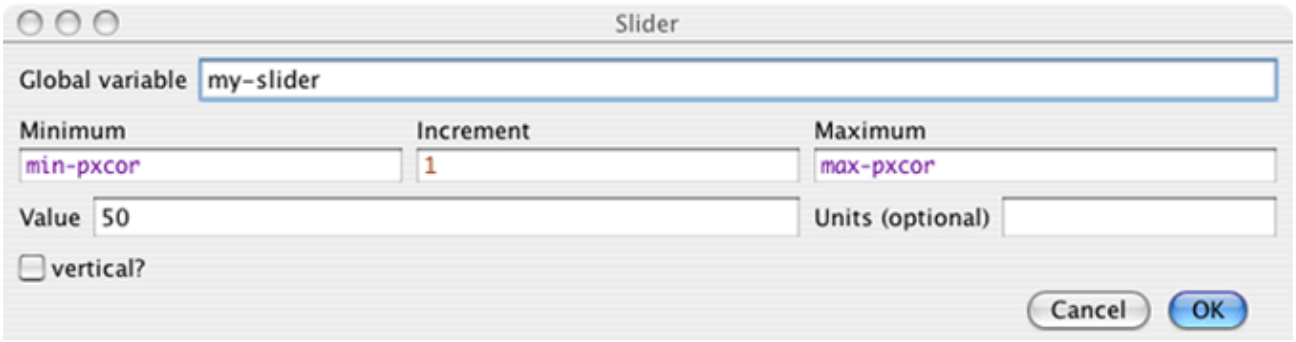
All the items in the box below the pen name are settings relevant to that particular pen.

- Set the color to one of the NetLogo base hues or a custom color using the color swatches.
- Mode allows you to change the appearance of the plot pen, line, bar (like a bar chart), or point (like line except the points are not connected)
- Interval is the amount by which x advances every time you use plot *y*
- If the Show in Legend checkbox is checked the selected pen will be a part of the legend in the upper right hand corner of the plot (which can be revealed by clicking on the word "Pens" on the plot itself).

For more detailed information on how each of these features works you can see the Plotting Section of the Programming Guide.

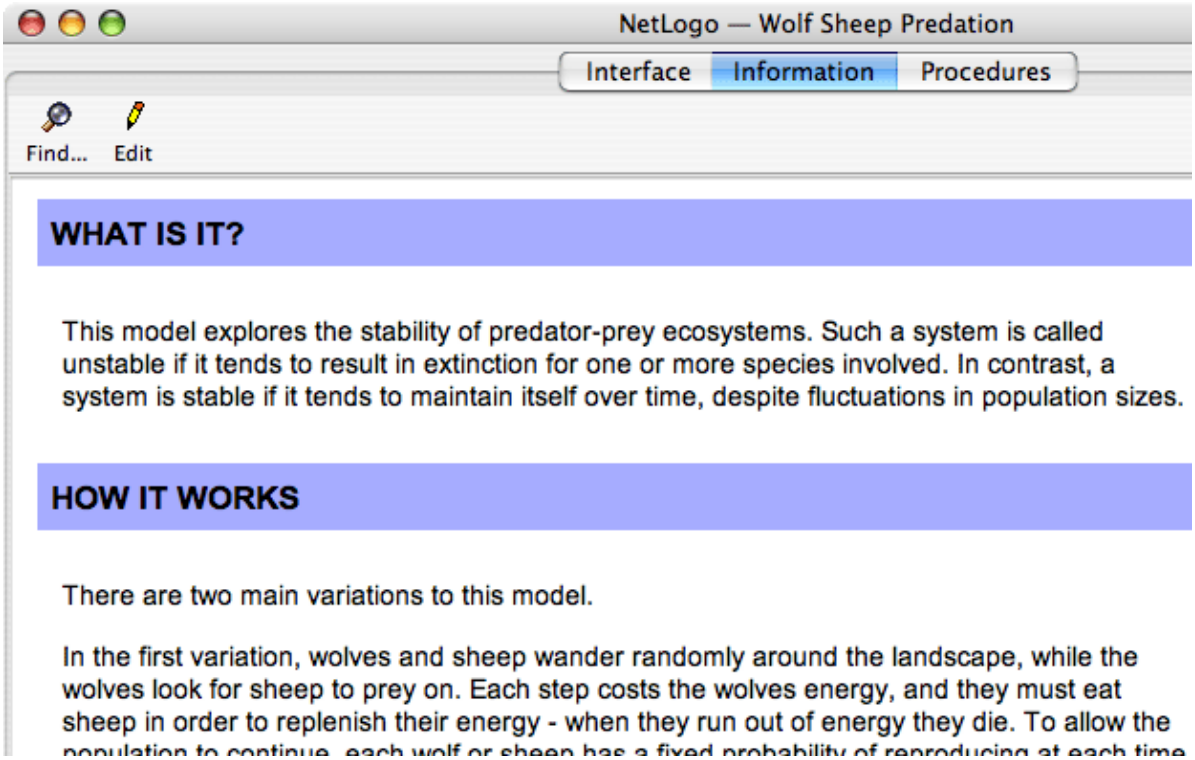
Sliders

Sliders define global variables, they are provided as an easy way to change the value of these global variables without changing the underlying code. When you place a slider in the Interface tab the edit dialog automatically opens, as with all widgets. Most of the fields will be familiar. However, it is important to notice the the minimum, maximum and increment fields will take any reporter expression, not just constants. So, for example, you could make the minimum `min-pxcor` and the maximum `max-pxcor` and the slider bounds will automatically adjust when you change the size of the world.

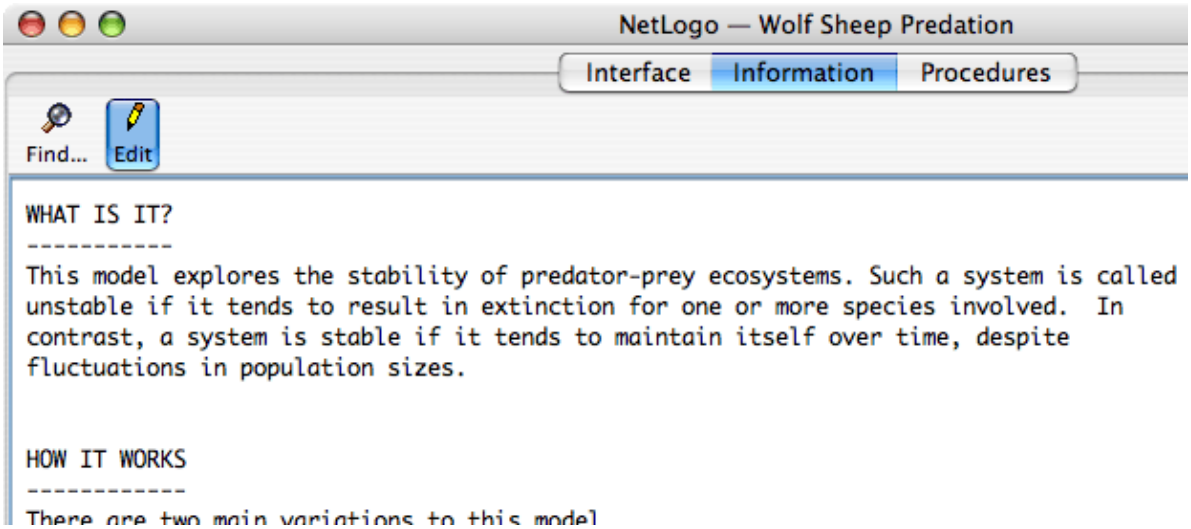


Information Tab

The Information tab provides an introduction to the model and an explanation of how to use it, things to explore, possible extensions, and NetLogo features. It is very helpful when you're first exploring a model.


NetLogo — Wolf Sheep Predation
Interface
Information
Procedures
Find...
Edit
WHAT IS IT?
This model explores the stability of predator-prey ecosystems. Such a system is called unstable if it tends to result in extinction for one or more species involved. In contrast, a system is stable if it tends to maintain itself over time, despite fluctuations in population sizes.
HOW IT WORKS
There are two main variations to this model.
In the first variation, wolves and sheep wander randomly around the landscape, while the wolves look for sheep to prey on. Each step costs the wolves energy, and they must eat sheep in order to replenish their energy - when they run out of energy they die. To allow the

We recommend reading the Information tab before starting the model. The Information tab explains what principle is being modeled and how the model was created. This display of the Information tab is not editable. To edit the content of the Info tab click the "Edit" button or double click on a word which will also scroll you to the location you clicked on and highlight the word.


NetLogo — Wolf Sheep Predation
Interface
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Find...
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WHAT IS IT?
This model explores the stability of predator-prey ecosystems. Such a system is called unstable if it tends to result in extinction for one or more species involved. In contrast, a system is stable if it tends to maintain itself over time, despite fluctuations in population sizes.
HOW IT WORKS
There are two main variations to this model

You can edit the text in this view as in any text editor. However, a few different forms will be displayed specially when you switch out of the edit view.

Information Tab Markup

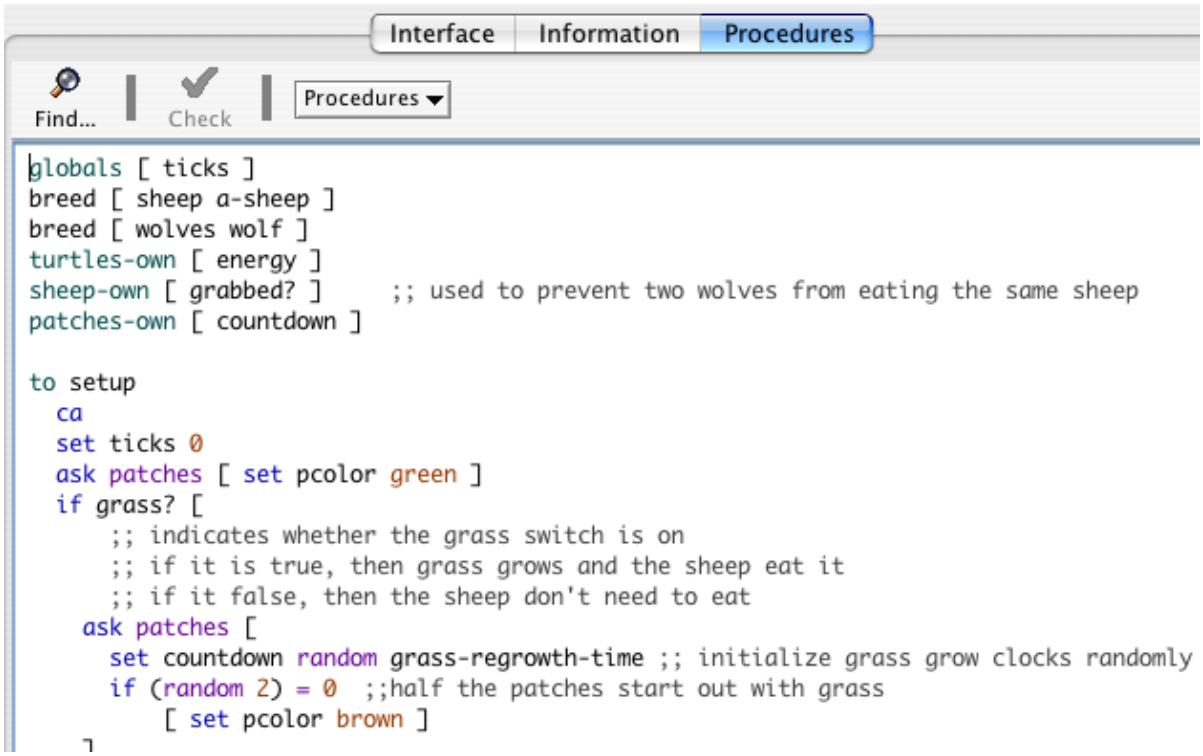
Description	Edit Mode	View Mode
Lines that come after blank lines and contain capital letters and no lower case letters become section headers.	WHAT IS IT	**WHAT IS IT**
Any line that has only dashes is omitted.	----------	
Anything beginning with "http://" becomes a clickable hyperlink.	http://ccl.northwestern.edu	http://ccl.northwestern.edu
E−mail addresses become clickable "mailto:" links.	bugs@ccl.northwestern.edu	bugs@ccl.northwestern.edu
Lines that begin with the pipe '|' (shift + backslash '\') become monospaced text. This is useful for diagrams and complicated	| this is preformatted text | you can put spaces in it	`this is preformatted text` `you can put spaces in it`

formulas, among other things.		

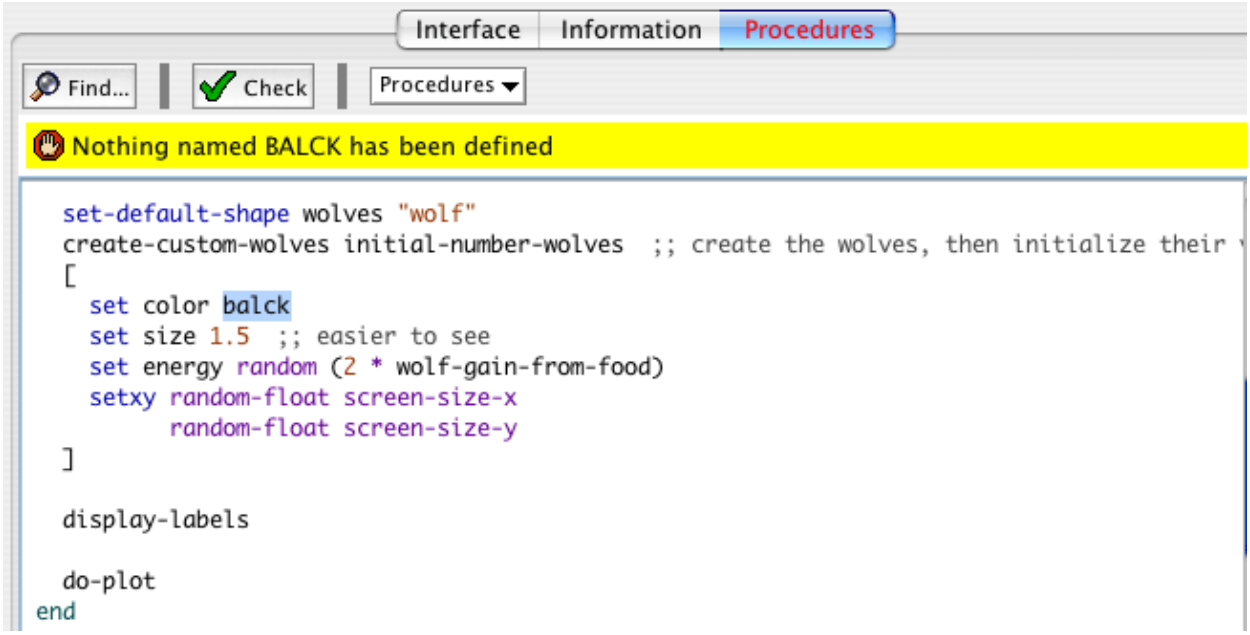
To return to the normal view, click the edit button.

Procedures Tab

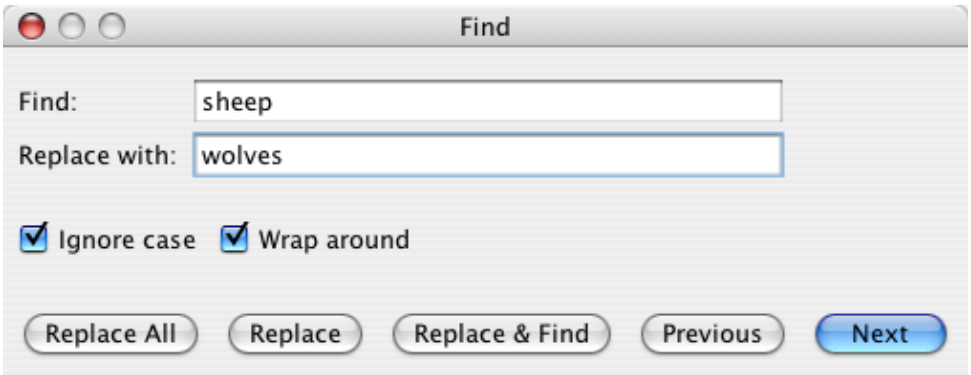
This tab is the workspace where the code for the model is stored. Commands you only want to use immediately go in the Command Center; commands you want to save and use later, over and over again, are found in the Procedures tab.


Interface
Information
Procedures
Find...
Check
Procedures
globals [ticks]
breed [sheep a-sheep]
breed [wolves wolf]
turtles-own [energy]
sheep-own [grabbed?] ;; used to prevent two wolves from eating the same sheep
patches-own [countdown]
to setup
ca
set ticks 0
ask patches [set pcolor green]
if grass? [
;; indicates whether the grass switch is on
;; if it is true, then grass grows and the sheep eat it
;; if it false, then the sheep don't need to eat
ask patches [
set countdown random grass-regrowth-time ;; initialize grass grow clocks randomly
if (random 2) = 0 ;;half the patches start out with grass
[set pcolor brown]

To determine if the code has any errors, you may press the "Check" button. If there are any syntax errors, the Procedures tab will turn red and the code that contains the error will be highlighted and a comment will appear in the top box. Switching tabs also causes the code to be checked and any errors will be shown, so if you switch tabs, pressing the Check button first isn't necessary.



To find a fragment of code in the procedures, click on the "Find" button in the Procedures Toolbar and the Find dialog will appear.



You may enter either a word or phrase to find or a word or phrase to find and one to replace it with. The "Ignore case" checkbox controls whether the capitalization must be the same to indicate a match. If the "Wrap around" checkbox is checked the entire Procedures tab will be checked for the phrase, starting at the cursor position, when it reaches the end it will return to the top, otherwise only the area from the cursor position to the end of the Procedures tab will be searched. The "Next" and "Previous" buttons will move down and up to find another occurrence of the search phrase. "Replace" changes the currently selected phrase with the replace phrase and "Replace & Find" changes the selected phrase and moves to the next occurrence. "Replace all" will change all instances of the the find phrase in the search area with the replace phrase.

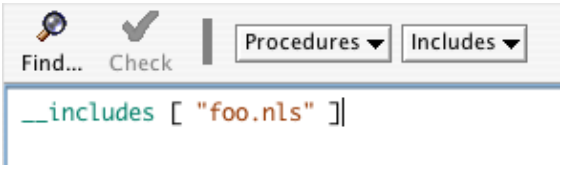
To find a particular procedure definition in your code, use the "Procedures" popup menu in the Procedures Toolbar. The menu lists all procedures in alphabetical order.

The "Shift Left", "Shift Right", "Comment", and "Uncomment" items on the Edit menu are used in the procedures tab to change the indentation level of your code or add and remove semicolons, which mark comments, from sections of code.

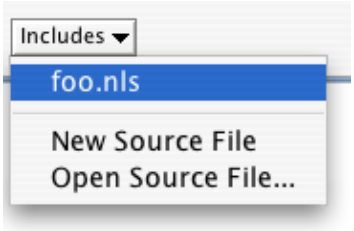
For more information about writing procedures, read Tutorial #3: Procedures and the Programming Guide.

Includes Menu

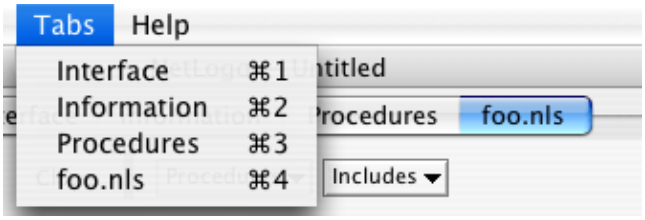
When you add the __includes keyword to a model a menu to the right of the procedures menu appears. This is the includes menu which lists all the NetLogo source files (.nls) included in this file (either .nlogo or .nls).



You can click on the file names in the menu to open a new tab containing that file, or you can open new files, or files in the file system using the other New Source File and Open Source File respectively.



Once you've opened new tabs you can navigate them similarly to the other tabs. They are accessible from the Tabs menu and you can use the keyboard to move from tab to tab (Command + number on Mac, Control + number on other operating systems).



Programming Guide

The following material explains some important features of programming in NetLogo.

The Code Example models mentioned throughout can be found in the Code Examples section of the Models Library.

- Agents
- Procedures
- Variables
- Colors
- Ask
- Agentsets
- Breeds
- Buttons
- Lists
- Math
- Random Numbers
- Turtle Shapes
- Link Shapes
- Tick Counter
- View Updates
- Plotting
- Strings
- Output
- File I/O
- Movies
- Perspective
- Drawing
- Topology
- Links
- Ask−Concurrent
- Tie
- Syntax

Agents

The NetLogo world is made up of agents. Agents are beings that can follow instructions. Each agent can carry out its own activity, all simultaneously.

In NetLogo, there are four types of agents: turtles, patches, links, and the observer. Turtles are agents that move around in the world. The world is two dimensional and is divided up into a grid of patches. Each patch is a square piece of "ground" over which turtles can move. Links are agents that connect two turtles. The observer doesn't have a location −− you can imagine it as looking out over the world of turtles and patches.

When NetLogo starts up, there are no turtles yet. The observer can make new turtles. Patches can make new turtles too. (Patches can't move, but otherwise they're just as "alive" as turtles and the observer are.)

Patches have coordinates. The patch at coordinates (0, 0) is called the origin and the coordinates of the other patches are the horizontal and vertical distances from this one. We call the patch's coordinates `pxcor` and `pycor`. Just like in the standard mathematical coordinate plane, `pxcor` increases as you move to the right and `pycor` increases as you move up.

The total number of patches is determined by the settings `min-pxcor`, `max-pxcor`, `min-pycor` and `max-pycor`. When NetLogo starts up, `min-pxcor`, `max-pxcor`, `min-pycor` and `max-pycor` are −16, 16, −16, and 16 respectively. This means that `pxcor` and `pycor` both range from −16 to 16, so there are 33 times 33, or 1089 patches total. (You can change the number of patches with the Settings button.)

Turtles have coordinates too: `xcor` and `ycor`. A patch's coordinates are always integers, but a turtle's coordinates can have decimals. This means that a turtle can be positioned at any point within its patch; it doesn't have to be in the center of the patch.

Links do not have coordinates, instead they have two endpoints (each a turtle). Links appear between the two endpoints, along the shortest path possible even if that means wrapping around the world.

The way the world of patches is connected can change. By default the world is a torus which means it isn't bounded, but "wraps" −− so when a turtle moves past the edge of the world, it disappears and reappears on the opposite edge and every patch has the same number of "neighbor" patches; if you're a patch on the edge of the world, some of your "neighbors" are on the opposite edge. However, you can change the wrap settings with the Settings button. If wrapping is not allowed in a given direction then in that direction (x or y) the world is bounded. Patches along that boundary will have fewer than 8 neighbors and turtles will not move beyond the edge of the world. See the Topology section for more information.

Procedures

In NetLogo, commands and reporters tell agents what to do. A **command** is an action for an agent to carry out. A **reporter** computes a result and report it.

Most commands begin with verbs ("create", "die", "jump", "inspect", "clear"), while most reporters are nouns or noun phrases.

Commands and reporters built into NetLogo are called **primitives**. The NetLogo Dictionary has a complete list of built−in commands and reporters.

Commands and reporters you define yourself are called **procedures**. Each procedure has a name, preceded by the keyword `to`. The keyword `end` marks the end of the commands in the procedure. Once you define a procedure, you can use it elsewhere in your program.

Many commands and reporters take **inputs** −− values that the command or reporter uses in carrying out its actions.

Examples: Here are two command procedures:

```
to setup
  clear-all      ;; clear the world
  crt 10         ;; make 10 new turtles
```

```
end

to go
  ask turtles
    [ fd 1             ;; all turtles move forward one step
      rt random 10     ;; ...and turn a random amount
      lt random 10 ]
end
```

Note the use of semicolons to add "comments" to the program. Comments make your program easier to read and understand.

In this program,

- `setup` and `go` are user−defined commands.
- `clear−all`, `crt` ("create turtles"), `ask`, `lt` ("left turn"), and `rt` ("right turn") are all primitive commands.
- `random` and `turtles` are primitive reporters. `random` takes a single number as an input and reports a random integer that is less than the input (in this case, between 0 and 9). `turtles` reports the agentset consisting of all the turtles. (We'll explain about agentsets later.)

`setup` and `go` can be called by other procedures or by buttons. Many NetLogo models have a once button that calls a procedure called `setup`, and a forever button that calls a procedure called `go`.

In NetLogo, you must specify which agents −− turtles, patches, links, or the observer −− are to run each command. (If you don't specify, the code is run by the observer.) In the code above, the observer uses `ask` to make the set of all turtles run the commands between the square brackets.

`clear−all` and `crt` can only be run by the observer. `fd`, on the other hand, can only be run by turtles. Some other commands and reporters, such as `set`, can be run by different agent types.

Here are some more advanced features you can take advantage of when defining your own procedures.

Procedures with inputs

Your own procedures can take inputs, just like primitives do. To create a procedure that accepts inputs, include a list of input names in square brackets after the procedure name. For example:

```
to draw−polygon [num−sides len]
  pen−down
  repeat num−sides
    [ fd len
      rt 360 / num−sides ]
end
```

Elsewhere in the program, you could ask turtles to each draw an octagon with a side length equal to its who number:

```
ask turtles [ draw−polygon 8 who ]
```

Reporter procedures

Just like you can define your own commands, you can define your own reporters. You must do two special things. First, use `to-report` instead of `to` to begin your procedure. Then, in the body of the procedure, use `report` to report the value you want to report.

```
to-report absolute-value [number]
  ifelse number >= 0
    [ report number ]
    [ report (- number) ]
end
```

Variables

Variables are places to store values (such as numbers). A variable can be a global variable, a turtle variable, or a patch variable.

If a variable is a global variable, there is only one value for the variable, and every agent can access it. But each turtle has its own value for every turtle variable, and each patch has its own value for every patch variable.

Some variables are built into NetLogo. For example, all turtles have a `color` variable, and all patches have a `pcolor` variable. (The patch variable begins with "p" so it doesn't get confused with the turtle variable.) If you set the variable, the turtle or patch changes color. (See next section for details.)

Other built-in turtle variables including `xcor`, `ycor`, and `heading`. Other built-in patch variables include `pxcor` and `pycor`. (There is a complete list here.)

You can also define your own variables. You can make a global variable by adding a switch or a slider to your model, or by using the `globals` keyword at the beginning of your code, like this:

```
globals [ score ]
```

You can also define new turtle, patch and link variables using the `turtles-own` , `patches-own` and `links-own` keywords, like this:

```
turtles-own [energy speed]
patches-own [friction]
links-own [strength]
```

These variables can then be used freely in your model. Use the `set` command to set them. (If you don't set them, they'll start out storing a value of zero.)

Global variables can be read and set at any time by any agent. As well, a turtle can read and set patch variables of the patch it is standing on. For example, this code:

```
ask turtles [ set pcolor red ]
```

causes every turtle to make the patch it is standing on red. (Because patch variables are shared by turtles in this way, you can't have a turtle variable and a patch variable with the same name.)

In other situations where you want an agent to read a different agent's variable, you can use `of`. Example:

```
show [color] of turtle 5
;; prints current color of turtle with who number 5
```

You can also use `of` with a more complicated expression than just a variable name, for example:

```
show [xcor + ycor] of turtle 5
;; prints the sum of the x and y coordinates of
;; turtle with who number 5
```

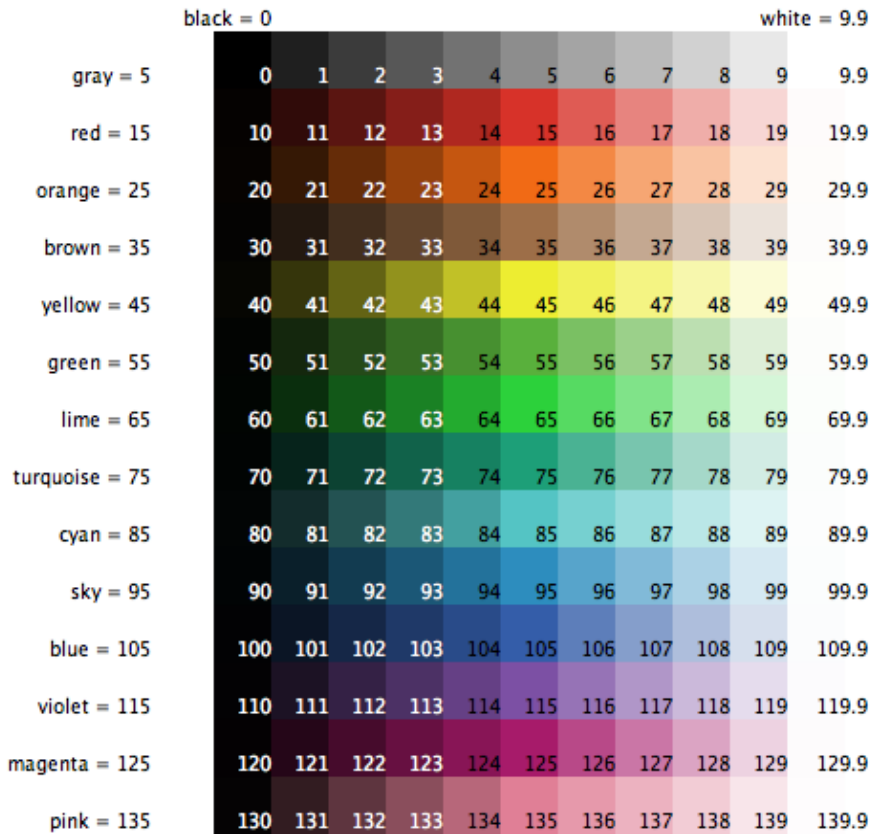
Local variables

A local variable is defined and used only in the context of a particular procedure or part of a procedure. To create a local variable, use the `let` command. You can use this command anywhere. If you use it at the top of a procedure, the variable will exist throughout the procedure. If you use it inside a set of square brackets, for example inside an "ask", then it will exist only inside those brackets.

```
to swap-colors [turtle1 turtle2]
  let temp [color] of turtle1
  ask turtle1 [ set color [color] of turtle2 ]
  ask turtle2 [ set color temp ]
end
```

Colors

NetLogo represents colors in two different ways. First, as numbers in the range 0 to 140, with the exception of 140 itself. Below is a chart showing the range of colors you can use in NetLogo.



The chart shows that:

- Some of the colors have names. (You can use these names in your code.)
- Every named color except black and white has a number ending in 5.
- On either side of each named color are darker and lighter shades of the color.
- 0 is pure black. 9.9 is pure white.
- 10, 20, and so on are all so dark they appear black.
- 19.9, 29.9 and so on are all so light they appear white.

Code Example: The color chart was made in NetLogo with the Color Chart Example model.

If you use a number outside the 0 to 140 range, NetLogo will repeatedly add or subtract 140 from the number until it is in the 0 to 140 range. For example, 25 is orange, so 165, 305, 445, and so on are orange too, and so are −115, −255, −395, etc. This calculation is done automatically whenever you set the turtle variable `color` or the patch variable `pcolor`. Should you need to perform this calculation in some other context, use the `wrap-color` primitive.

If you want a color that's not on the chart, more can be found between the integers. For example, 26.5 is a shade of orange halfway between 26 and 27. This doesn't mean you can make any color in NetLogo; the NetLogo color space is only a subset of all possible colors. It contains only a fixed set of discrete hues (one hue per row of the chart). Starting from one of those hues, you can either decrease its brightness (darken it) or decrease its saturation (lighten it), but you cannot decrease both brightness and saturation. Also, only the first digit after the decimal point is significant. Thus, color values are rounded down to the next 0.1, so for example, there's no visible difference between 26.5 and 26.52 or 26.58.

Color primitives

There are a few primitives that are helpful for working with colors.

We have already mentioned the `wrap-color` primitive.

The `scale-color` primitive is useful for converting numeric data into colors.

`shade-of?` will tell you if two colors are "shades" of the same basic hue. For example, `shade-of? orange 27` is true, because 27 is a lighter shade of orange.

Code Example: Scale−color Example demonstrates the scale−color reporter.

RGB Colors

The second color representation in NetLogo is an RGB (red/green/blue) list. When using RGB colors the full range of colors is available to you. RGB lists are made up of three integers between 0 and 255 if a number is outside that range 255 is repeatedly subtracted until it is in the range. You can set any color variables in NetLogo (`color` for turtles and links and `pcolor` for patches) to an RGB list and that agent will be rendered appropriately. So you can set the color of patch 0 0 to pure

red using the following code:

```
set pcolor [255 0 0]
```

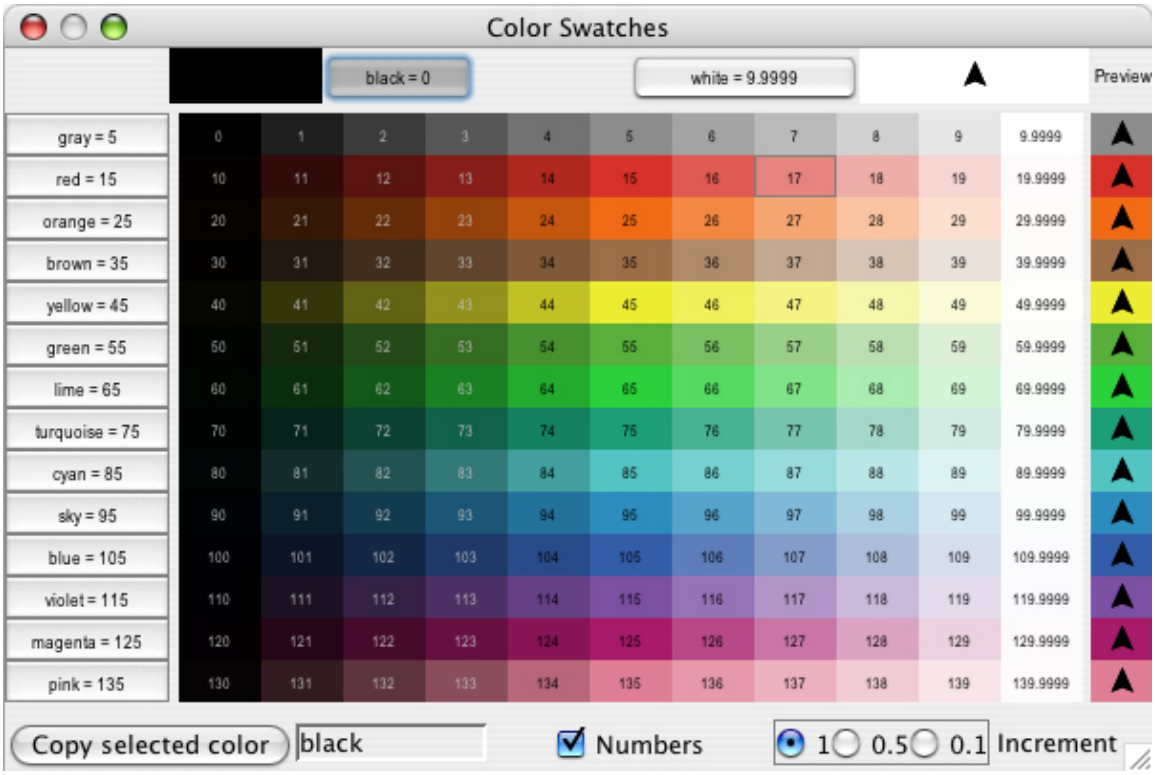
You can convert between RGB, HSB (hue/saturation/brightness), and NetLogo colors using `approximate-hsb` and `approximate-rgb` from RGB/HSB to NetLogo colors, and `extract-hsb` and `extract-rgb` in the opposite direction. You can use `rgb` to generate rgb lists and `hsb` to convert from an HSB color to RGB.

Since many colors are missing from the NetLogo color space, `approximate-hsb` and `approximate-rgb` often can't give you the exact color you ask for, but they try to come as close as possible.

> **Code Example:** The HSB and RGB Example model lets you experiment with the HSB and RGB color systems.

Color Swatches dialog

The Color Swatches dialog helps you experiment with and choose colors. Open it by choosing Color Swatches on the Tools Menu.



When you click on a color swatch (or a color button), that color will be shown against other colors. In the bottom left, the code for the currently selected color is displayed (for example, `red + 2`) so you can copy and paste it into your code. On the bottom right there are three increment options, 1, 0.5, and 0.1. These numbers indicate the difference between two adjacent swatches. When the increment is 1 there are 10 different shades in each row; when the increment is 0.1 there are 100

different shades in each row. 0.5 is an intermediate setting.

Ask

NetLogo uses the ask command to give commands to turtles, patches, and links. All code to be run by turtles **must** be located in a turtle "context". You can establish a turtle context in any of three ways:

- In a button, by choosing "Turtles" from the popup menu. Any code you put in the button will be run by all turtles.
- In the Command Center, by choosing "Turtles" from the popup menu. Any commands you enter will be run by all the turtles.
- By using `ask turtles`.

The same goes for patches, links, and the observer, except that you cannot `ask` the observer. Any code that is not inside any `ask` is by default observer code.

Here's an example of the use of `ask` in a NetLogo procedure:

```
to setup
  clear-all
  crt 100              ;; create 100 turtles
  ask turtles
    [ set color red    ;; turn them red
      rt random-float 360    ;; give them random headings
      fd 50 ]          ;; spread them around
  ask patches
    [ if pxcor > 0         ;; patches on the right side
        [ set pcolor green ] ]  ;; of the view turn green
end
```

The models in the Models Library are full of other examples. A good place to start looking is in the Code Examples section.

Usually, the observer uses `ask` to ask all turtles, all patches or all links to run commands. You can also use `ask` to have an individual turtle, patch or link run commands. The reporters `turtle`, `patch`, `link` and `patch-at` are useful for this technique. For example:

```
to setup
  clear-all
  crt 3                          ;; make 3 turtles
  ask turtle 0                   ;; tell the first one...
    [ fd 1 ]                     ;; ...to go forward
  ask turtle 1                   ;; tell the second one...
    [ set color green ]          ;; ...to become green
  ask turtle 2                   ;; tell the third one...
    [ rt 90 ]                    ;; ...to turn right
  ask patch 2 -2                 ;; ask the patch at (2,-2)
    [ set pcolor blue ]          ;; ...to become blue
  ask turtle 0                   ;; ask the first turtle
    [ ask patch-at 1 0           ;; ...to ask patch to the east
      [ set pcolor red ] ]       ;; ...to become red
  ask turtle 0                   ;; tell the first turtle...
    [ create-link-with turtle 1 ] ;; ...make a link with the second
  ask link 0 1                   ;; tell the link between turtle 0 and 1
    [ set color blue ]           ;; ...to become blue
```

```
end
```

Every turtle created has a who number. The first turtle created is number 0, the second turtle number 1, and so forth. The `turtle` primitive reporter takes a who number as an input, and reports the turtle with that who number. The `patch` primitive reporter takes values for pxcor and pycor and reports the patch with those coordinates. The `link` primitive takes two inputs, the who numbers of the two turtles it connects. And the `patch-at` primitive reporter takes *offsets*: distances, in the `x` and `y` directions, *from* the first agent. In the example above, the turtle with who number 0 is asked to get the patch east (and no patches north) of itself.

You can also select a subset of turtles, or a subset of patches, or a subset of links and ask them to do something. This involves a concept called "agentsets". The next section explains this concept in detail.

When you ask a set of agents to run more than one command, each agent must finish before the next agent starts. One agent runs all of the commands, then the next agent runs all of them, and so on. For example, if you write:

```
ask turtles
  [ fd 1
    set color red ]
```

first one turtle moves and turns red, then another turtle moves and turns red, and so on.

But if you write it this way:

```
ask turtles [ fd 1 ]
ask turtles [ set color red ]
```

first all of the turtles move. After they have all moved, they all turn red.

(Another form of the `ask` command, with a different ordering rule, is also available. See Ask-Concurrent below.)

Agentsets

An agentset is exactly what its name implies, a set of agents. An agentset can contain either turtles, patches or links, but not more than one type at once.

An agentset is not in any particular order. In fact, it's always in a random order. And every time you use it, the agentset is in a *different* random order. This helps you keep your model from treating any particular turtles, patches or links differently from any others (unless you want them to be). Since the order is random every time, no one agent always gets to go first.

You've seen the `turtles` primitive, which reports the agentset of all turtles, the `patches` primitive, which reports the agentset of all patches and the `links` primitive which reports the agentset of all links.

But what's powerful about the agentset concept is that you can construct agentsets that contain only *some* turtles, *some* patches or *some* links. For example, all the red turtles, or the patches with pxcor evenly divisible by five, or the turtles in the first quadrant that are on a green patch or the links

connected to turtle 0. These agentsets can then be used by `ask` or by various reporters that take agentsets as inputs.

One way is to use `turtles-here` or `turtles-at`, to make an agentset containing only the turtles on my patch, or only the turtles on some other particular patch. There's also `turtles-on` so you can get the set of turtles standing on a given patch or set of patches, or the set of turtles standing on the same patch as a given turtle or set of turtles.

Here are some more examples of how to make agentsets:

```
;; all other turtles:
other turtles
;; all other turtles on this patch:
other turtles-here
;; all red turtles:
turtles with [color = red]
;; all red turtles on my patch
turtles-here with [color = red]
;; patches on right side of view
patches with [pxcor > 0]
;; all turtles less than 3 patches away
turtles in-radius 3
;; the four patches to the east, north, west, and south
patches at-points [[1 0] [0 1] [-1 0] [0 -1]]
;; shorthand for those four patches
neighbors4
;; turtles in the first quadrant that are on a green patch
turtles with [(xcor > 0) and (ycor > 0)
              and (pcolor = green)]
;; turtles standing on my neighboring four patches
turtles-on neighbors4
;; all the links connected to turtle 0
[my-links] of turtle 0
```

Note the use of `other` to exclude the calling agent. This is common.

Once you have created an agentset, here are some simple things you can do:

- Use `ask` to make the agents in the agentset do something
- Use `any?` to see if the agentset is empty
- Use `all?` to see if every agent in an agentset satisfies a condition.
- Use `count` to find out exactly how many agents are in the set

And here are some more complex things you can do:

- Pick a random agent from the set using `one-of`. For example, we can make a randomly chosen turtle turn green:

  ```
  ask one-of turtles [ set color green ]
  ```

  Or tell a randomly chosen patch to `sprout` a new turtle:

  ```
  ask one-of patches [ sprout 1 ]
  ```
- Use the `max-one-of` or `min-one-of` reporters to find out which agent is the most or least along some scale. For example, to remove the richest turtle, you could say

```
ask max-one-of turtles [sum assets] [ die ]
```

- Make a histogram of the agentset using the `histogram` command (in combination with `of`).
- Use `of` to make a list of values, one for each agent in the agentset. Then use one of NetLogo's list primitives to do something with the list. (See the "Lists" section below.) For example, to find out how rich turtles are on the average, you could say

```
show mean [sum assets] of turtles
```

- Use `turtle-set`, `patch-set` and `link-set` reporters to make new agentsets by gathering together agents from a variety of possible sources.
- Check whether two agentsets are equal using = or `!=`.
- Use `member?` to see whether a particular agent is a member of an agentset.

This only scratches the surface. See the Models Library for many more examples, and consult the NetLogo Dictionary for more information about all of the agentset primitives.

More examples of using agentsets are provided in the individual entries for these primitives in the NetLogo Dictionary. In developing familiarity with programming in NetLogo, it is important to begin to think of compound commands in terms of how each element passes information to the next one. Agentsets are an important part of this conceptual scheme and provide the NetLogo developer with a lot of power and flexibility, as well as being more similar to natural language.

Code Example: Ask Ordering Example

Earlier, we said that agentsets are always in random order, a different random order every time. If you need your agents to do something in a fixed order, you need to make a list of the agents instead. See the Lists section below.

Breeds

NetLogo allows you to define different "breeds" of turtles and breeds of links. Once you have defined breeds, you can go on and make the different breeds behave differently. For example, you could have breeds called `sheep` and `wolves`, and have the wolves try to eat the sheep or you could have link breeds called `streets` and `sidewalks` where foot traffic is routed on sidewalks and car traffic is routed on streets.

You define turtle breeds using the `breed` keyword, at the top of the Procedures tab, before any procedures:

```
breed [wolves wolf]
breed [sheep a-sheep]
```

You can refer to a member of the breed using the singular form, just like the turtle reporter. When printed, members of the breed will be labeled with the singular name.

Some commands and reporters have the plural name of the breed in them, such as create-<breeds>. Others have the singular name of the breed in them, such as <breed>

The order in which breeds are declared is also the order order in which they are layered in the view. So breeds defined later will appear on top of breeds defined earlier; in this example, sheep will be

drawn over wolves.

When you define a breed such as `sheep`, an agentset for that breed is automatically created, so that all of the agentset capabilities described above are immediately available with the `sheep` agentset.

The following new primitives are also automatically available once you define a breed: `create-sheep`, `hatch-sheep`, `sprout-sheep`, `sheep-here`, `sheep-at`, `sheep-on`, and `is-a-sheep?`.

Also, you can use `sheep-own` to define new turtle variables that only turtles of the given breed have.

A turtle's breed agentset is stored in the `breed` turtle variable. So you can test a turtle's breed, like this:

```
if breed = wolves [ ... ]
```

Note also that turtles can change breeds. A wolf doesn't have to remain a wolf its whole life. Let's change a random wolf into a sheep:

```
ask one-of wolves [ set breed sheep ]
```

The `set-default-shape` primitive is useful for associating certain turtle shapes with certain breeds. See the section on shapes below.

Here is a quick example of using breeds:

```
breed [mice mouse]
breed [frogs frog]
mice-own [cheese]
to setup
  clear-all
  create-mice 50
    [ set color white
      set cheese random 10 ]
  create-frogs 50
    [ set color green ]
end
```

Code Example: Breeds and Shapes Example

Link Breeds

Link breeds are very similar to turtle breeds, however, there are a few differences.

When you declare a link breed you must declare whether it is a breed of directed or undirected links by using the `directed-link-breed` and `undirected-link-breed` keywords.

```
directed-link-breed [streets street]
undirected-link-breed [friendships friendship]
```

once you have created a breeded link you cannot create unbreeded links and vice versa. (You can, however, have directed and undirected links in the same world, just not in the same breed)

Unlike with turtle breeds the singular breed name is required for link breeds, as many of the link commands and reports use the singular name, such as `<link-breed>-neighbor?`.

The following primitives are also automatically available once you define a directed link breed: `create-street-from` `create-streets-from` `create-street-to` `create-streets-to` `in-street-neighbor?` `in-street-neighbors` `in-street-from` `my-in-streets` `my-out-streets` `out-street-neighbor?` `out-street-neighbors` `out-street-to`

And the following are automatically available when you define an undirected link breed: `create-friendship-with` `create-friendships-with` `friendship-neighbor?` `friendship-neighbors` `friendship-with` `my-friendships`

Just as with turtle breeds the order in which link breeds are declared defines the order in which the links are drawn, so the friendships will always be on top of streets (if for some reason these breeds were in the same model). You can also use `<link-breeds>-own` to declare variables of each link breed separately.

You can change the breed of links, like turtles, however, you cannot the breed of links to be unbreeded links, to prevent having breeded and unbreeded links in the same world.

```
ask one-of friendships [ set breed streets ]
ask one-of friendships [ set breed links ] ;; produces a runtime error
```

`set-default-shape` may also be used with link breeds to associate it with a particular link shape.

Code Example: Link Breeds Example

Buttons

Buttons in the interface tab provide an easy way to control the model. Typically a model will have at least a "setup" button, to set up the initial state of the world, and a "go" button to make the model run continuously. Some models will have additional buttons that perform other actions.

A button contains some NetLogo code. That code is run when you press the button.

A button may be either a "once button", or a "forever button". You can control this by editing the button and checking or unchecking the "Forever" checkbox. Once buttons run their code once, then stop and pop back up. Forever buttons keep running their code over and over again, until either the code hits the `stop` command, or you press the button again to stop it. If you stop the button, the code doesn't get interrupted. The button waits until the code has finished, then pops up.

Normally, a button is labeled with the code that it runs. For example, a button that says "go" on it usually contains the code "go", which means "run the go procedure". (Procedures are defined in the Procedures tab; see below.) But you can also edit a button and enter a "display name" for the button, which is a text that appears on the button instead of the code. You might use this feature if you think the actual code would be confusing to your users.

When you put code in a button, you must also specify which agents you want to run that code. You can choose to have the observer run the code, or all turtles, or all patches, or all links. (If you want the code to be run by only some turtles or some patches, you could make an observer button, and then have the observer use the `ask` command to ask only some of the turtles or patches to do something.)

When you edit a button, you have the option to assign an "action key". This makes that key on the keyboard behave just like a button press. If the button is a forever button, it will stay down until the key is pressed again (or the button is clicked). Action keys are particularly useful for games or any model where rapid triggering of buttons is needed.

Buttons take turns

More than one button can be pressed at a time. If this happens, the buttons "take turns", which means that only one button runs at a time. Each button runs its code all the way through once while the other buttons wait, then the next button gets its turn.

In the following examples, "setup" is a once button and "go" is a forever button.

Example #1: The user presses "setup", then presses "go" immediately, before the "setup" has popped back up. Result: "setup" finishes before "go" starts.

Example #2: While the "go" button is down, the user presses "setup". Result: the "go" button finishes its current iteration. Then the "setup" button runs. Then "go" starts running again.

Example #3: The user has two forever buttons down at the same time. Result: first one button runs its code all the way through, then the other runs its code all the way through, and so on, alternating.

Note that if one button gets stuck in an infinite loop, then no other buttons will run.

Turtle, patch, and link forever buttons

There is a subtle difference between putting commands in a turtle, patch or link forever button, and putting the same commands in an observer button that does `ask turtles`, `ask patches` or `ask links`. An "ask" doesn't complete until all of the agents have finished running all of the commands in the "ask". So the agents, as they all run the commands concurrently, can be out of sync with each other, but they all sync up again at the end of the ask. The same isn't true of turtle, patch and link forever buttons. Since `ask` was not used, each turtle or patch runs the given code over and over again, so they can become (and remain) out of sync with each other.

At present, this capability is very rarely used in the models in our Models Library. A model that does use the capability is the Termites model, in the Biology section of Sample Models. The "go" button is a turtle forever button, so each termite proceeds independently of every other termite, and the observer is not involved at all. This means that if, for example, you wanted to add a plot to the model, you would need to add a second forever button (an observer forever button), and run both forever buttons at the same time.

At present, NetLogo has no way for one forever button to start another. Buttons are only started when you press them.

Lists

In the simplest models, each variable holds only one piece of information, usually a number or a string. The list feature lets you store multiple pieces of information in a single variable by collecting those pieces of information in a list. Each value in the list can be any type of value: a number, or a string, an agent or agentset, or even another list.

Lists allow for the convenient packaging of information in NetLogo. If your agents carry out a repetitive calculation on multiple variables, it might be easier to have a list variable, instead of multiple number variables. Several primitives simplify the process of performing the same computation on each value in a list.

The NetLogo Dictionary has a section that lists all of the list−related primitives.

Constant lists

You can make a list by simply putting the values you want in the list between brackets, like this: `set mylist [2 4 6 8]`. Note that the individual values are separated by spaces. You can make lists that contain numbers and strings this way, as well as lists within lists, for example `[[2 4] [3 5]]`.

The empty list is written by putting nothing between the brackets, like this: `[]`.

Building lists on the fly

If you want to make a list in which the values are determined by reporters, as opposed to being a series of constants, use the `list` reporter. The `list` reporter accepts two other reporters, runs them, and reports the results as a list.

If I wanted a list to contain two random values, I might use the following code:

```
set random−list list (random 10) (random 20)
```

This will set `random−list` to a new list of two random integers each time it runs.

To make longer or shorter lists, you can use the `list` reporter with fewer or more than two inputs, but in order to do so, you must enclose the entire call in parentheses, e.g.:

```
(list random 10)
(list random 10 random 20 random 30)
```

For more information, see Varying number of inputs.

Some kinds of lists are most easily built using the n−values reporter, which allows you to construct a list of a specific length by repeatedly running a given reporter. You can make a list of the same value repeated, or all the numbers in a range, or a lot of random numbers, or many other possibilities. See dictionary entry for details and examples.

The of primitive lets you construct a list from an agentset. It reports a list containing each agent's value for the given reporter. (The reporter could be a simple variable name, or a more complex expression −− even a call to a procedure defined using `to−report`.) A common idiom is

```
max [...] of turtles
sum [...] of turtles
```

and so on.

You can combine two or more lists using the sentence reporter, which concatenates lists by combining their contents into a single, larger list. Like `list`, `sentence` normally takes two inputs, but can accept any number of inputs if the call is surrounded by parentheses.

Changing list items

Technically, lists can't be modified, but you can construct new lists based on old lists. If you want the new list to replace the old list, use `set`. For example:

```
set mylist [2 7 5 Bob [3 0 -2]]
; mylist is now [2 7 5 Bob [3 0 -2]]
set mylist replace-item 2 mylist 10
; mylist is now [2 7 10 Bob [3 0 -2]]
```

The `replace-item` reporter takes three inputs. The first input specifies which item in the list is to be changed. 0 means the first item, 1 means the second item, and so forth.

To add an item, say 42, to the end of a list, use the `lput` reporter. (`fput` adds an item to the beginning of a list.)

```
set mylist lput 42 mylist
; mylist is now [2 7 10 Bob [3 0 -2] 42]
```

But what if you changed your mind? The `but-last` (`bl` for short) reporter reports all the list items but the last.

```
set mylist but-last mylist
; mylist is now [2 7 10 Bob [3 0 -2]]
```

Suppose you want to get rid of item 0, the 2 at the beginning of the list.

```
set mylist but-first mylist
; mylist is now [7 10 Bob [3 0 -2]]
```

Suppose you wanted to change the third item that's nested inside item 3 from −2 to 9? The key is to realize that the name that can be used to call the nested list [3 0 −2] is `item 3 mylist`. Then the `replace-item` reporter can be nested to change the list−within−a−list. The parentheses are added for clarity.

```
set mylist (replace-item 3 mylist
                 (replace-item 2 (item 3 mylist) 9))
; mylist is now [7 10 Bob [3 0 9]]
```

Iterating over lists

If you want to do some operation on each item in a list in turn, the `foreach` command and the `map` reporter may be helpful.

`foreach` is used to run a command or commands on each item in a list. It takes an input list and a block of commands, like this:

```
foreach [2 4 6]
  [ crt ?
    show (word "created " ? " turtles") ]
=> created 2 turtles
=> created 4 turtles
=> created 6 turtles
```

In the block, the variable ? holds the current value from the input list.

Here are some more examples of `foreach`:

```
foreach [1 2 3] [ ask turtles [ fd ? ] ]
;; turtles move forward 6 patches
foreach [true false true true] [ ask turtles [ if ? [ fd 1 ] ] ]
;; turtles move forward 3 patches
```

`map` is similar to `foreach`, but it is a reporter. It takes an input list and another reporter. Note that unlike `foreach`, the reporter comes first, like this:

```
show map [round ?] [1.2 2.2 2.7]
;; prints [1 2 3]
```

`map` reports a list containing the results of applying the reporter to each item in the input list. Again, use ? to refer to the current item in the list.

Here is another example of `map`:

```
show map [? < 0] [1 -1 3 4 -2 -10]
;; prints [false true false false true true]
```

`foreach` and `map` won't necessarily be useful in every situation in which you want to operate on an entire list. In some situations, you may need to use some other technique such as a loop using `repeat` or `while`, or a recursive procedure.

The sort-by primitive uses a similar syntax to `map` and `foreach`, except that since the reporter needs to compare two objects, the two special variables `?1` and `?2` are used in place of `?`.

Here is an example of `sort-by`:

```
show sort-by [?1 < ?2] [4 1 3 2]
;; prints [1 2 3 4]
```

Varying number of inputs

Some commands and reporters involving lists and strings may take a varying number of inputs. In these cases, in order to pass them a number of inputs other than their default, the primitive and its inputs must be surrounded by parentheses. Here are some examples:

```
show list 1 2
=> [1 2]
show (list 1 2 3 4)
```

```
=> [1 2 3 4]
show (list)
=> []
```

Note that each of these special commands has a default number of inputs for which no parentheses are required. The primitives which have this capability are list, word, sentence, map, and foreach.

Lists of agents

Earlier, we said that agentsets are always in random order, a different random order every time. If you need your agents to do something in a fixed order, you need to make a list of the agents instead.

There are two primitives that help you do this, `sort` and `sort-by`.

Both `sort` and `sort-by` can take an agentset as input. The result is always a new list, containing the same agents as the agentset did, but in a particular order.

If you use `sort` on an agentset of turtles, the result is a list of turtles sorted in ascending order by who number.

If you use `sort` on an agentset of patches, the result is a list of patches sorted left-to-right, top-to-bottom.

If you use `sort` on an agentset of links, the result is a list of links, sorted in ascending order first by `end1` then by `end2` any remaining ties are resolved by breed in the order they are declared in the procedures tab.

If you need descending order instead, you can combine `reverse` with `sort`, for example `reverse sort turtles`.

If you want your agents to be ordered by some other criterion than the standard ones `sort` uses, you'll need to use `sort-by` instead.

Here's an example:

```
sort-by [[size] of ?1 < [size] of ?2] turtles
```

This returns a list of turtles sorted in ascending order by their turtle variable `size`.

Asking a list of agents

Once you have a list of agents, you might want to ask them each to do something. To do this, use the `foreach` and `ask` commands in combination, like this:

```
foreach sort turtles [
  ask ? [
    ...
  ]
]
```

This will ask each turtle in ascending order by who number. Substitute "patches" for "turtles" to ask

patches in left−to−right, top−to−bottom order.

If you use foreach like this, the agents in the list run the commands inside the ask sequentially, not concurrently. Each agent finishes the commands before the next agent begins them.

Note that you can't use `ask` directly on a list of turtles. `ask` only works with agentsets and single agents.

Performance of lists

If your model makes especially heavy use of lists, especially long lists, you may need to know the speed of the various NetLogo list operations, to help you write code that runs fast.

NetLogo lists are "singly linked" lists. This is a technical term from computer science that means that when NetLogo needs to find an item in a list, it must start at the beginning of the list and go from item to item until it finds the one it wants. For example, to find the 100th item, NetLogo must step through the previous 99 items, one at a time.

It also means that certain operations are especially efficient, namely operations at the front of the list. The `first`, `butfirst`, and `fput` reporters are all very fast; they take the same amount of time to run, no matter how long the list is. So if you're building up a list by adding items to it one at a time, it's much faster to use `fput` than `lput`. (If that causes your list to end up backwards from how you wanted it, you can always use `reverse` to reverse the list once you're done building it.)

The `length` reporter is also fast; NetLogo always keeps track of how long every list is, so it never needs to actually measure.

Examples of reporters which are slower on longer lists include `item`, `lput`, `butlast`, `last`, and `one-of`.

Math

All numbers in NetLogo are stored internally as double precision floating point numbers, as defined in the IEEE 754 standard. They are 64 bit numbers consisting of one sign bit, an 11−bit exponent, and a 52−bit mantissa. See the IEEE 754 standard for details.

An "integer" in NetLogo is simply a number that happens to have no fractional part. No distinction is made between 3 and 3.0; they are the same number. (This is the same as how most people use numbers in everyday contexts, but different from some programming languages. Some languages treat integers and floating point numbers as distinct types.)

Integers are always printed by NetLogo without the trailing ".0":

```
show 1.5 + 1.5
observer: 3
```

If a number with a fractional part is supplied in a context where an integer is expected, the fractional part is simply discarded. So for example, `crt 3.5` creates three turtles; the extra 0.5 is ignored.

The range of integers is +/−9007199254740992 (2^53, about 9 quadrillion). Calculations that exceed this range will not cause runtime errors, but precision will be lost when the least significant

(binary) digits are rounded off in order fit the number into 64 bits. With very large numbers, this rounding can result in imprecise answers which may be surprising:

```
show 2 ^ 60 + 1 = 2 ^ 60
=> true
```

Calculations with smaller numbers can also produce surprising results if they involve fractional quantities, since not all fractions can be precisely represented and roundoff may occur. For example:

```
show 1 / 6 + 1 / 6 + 1 / 6 + 1 / 6 + 1 / 6 + 1 / 6
=> 0.9999999999999999
show 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9 + 1 / 9
=> 1.0000000000000002
```

Any operation which produces the special quantities "infinity" or "not a number" will cause a runtime error.

Scientific notation

Very large or very small floating point numbers are displayed by NetLogo using "scientific notation". Examples:

```
show 0.000000000001
=> 1.0E-12
show 50000000000000000000
=> 5.0E19
```

Numbers in scientific notation are distinguished by the presence of the letter E (for "exponent"). It means "times ten to the power of", so for example, 1.0E−12 means 1.0 times 10 to the −12 power:

```
show 1.0 * 10 ^ -12
=> 1.0E-12
```

You can also use scientific notation yourself in NetLogo code:

```
show 3.0E6
=> 3000000
show 8.123456789E6
=> 8123456.789
show 8.123456789E7
=> 8.123456789E7
show 3.0E16
=> 3.0E16
show 8.0E-3
=> 0.0080
show 8.0E-4
=> 8.0E-4
```

These examples show that numbers with fractional parts are displayed using scientific notation if the exponent is less than −3 or greater than 6. Numbers outside of NetLogo's integer range of −9007199254740992 to 9007199254740992 (+/−2^53) are also always shown in scientific notation:

```
show 2 ^ 60
=> 1.1529215046068470E18
```

When entering a number, the letter E may be either upper or lowercase. When printing a number, NetLogo always uses an uppercase E:

```
show 4.5e20
=> 4.5E20
```

Floating point accuracy

Because numbers in NetLogo are subject to the limitations of how floating point numbers are represented in binary, you may get answers that are slightly inaccurate. For example:

```
show 0.1 + 0.1 + 0.1
=> 0.30000000000000004
show cos 90
=> 6.123233995736766E-17
```

This is an inherent issue with floating point arithmetic; it occurs in all programming languages that use floating point numbers.

If you are dealing with fixed precision quantities, for example dollars and cents, a common technique is to use only integers (cents) internally, then divide by 100 to get a result in dollars for display.

If you must use floating point numbers, then in some situations you may need to replace a straightforward equality test such as `if x = 1 [ ... ]` with a test that tolerates slight imprecision, for example `if abs (x - 1) < 0.0001 [ ... ]`.

Also, the `precision` primitive is handy for rounding off numbers for display purposes. NetLogo monitors round the numbers they display to a configurable number of decimal places, too.

Random Numbers

The random numbers used by NetLogo are what is called "pseudo-random". (This is typical in computer programming.) That means they appear random, but are in fact generated by a deterministic process. "Deterministic" means that you get the same results every time, if you start with the same random "seed". We'll explain in a minute what we mean by "seed".

In the context of scientific modeling, pseudo-random numbers are actually desirable. That's because it's important that a scientific experiment be reproducible -- so anyone can try it themselves and get the same result that you got. Since NetLogo uses pseudo-random numbers, the "experiments" that you do with it can be reproduced by others.

Here's how it works. NetLogo's random number generator can be started with a certain seed value, which can be any integer. Once the generator has been "seeded" with the `random-seed` command, it always generates the same sequence of random numbers from then on. For example, if you run these commands:

```
random-seed 137
show random 100
show random 100
show random 100
```

You will always get the numbers 95, 7, and 54 in that order.

Note, however, that you're only guaranteed to get those same numbers if you're using the same version of NetLogo. Sometimes when we make a new version of NetLogo the random number generator changes. (Presently, we use a generator known as the Mersenne Twister.)

To create a number suitable for seeding the random number generator, use the new-seed reporter. new-seed creates a seed, evenly distributed over the space of possible seeds, based on the current date and time. It never reports the same seed twice in a row.

Code Example: Random Seed Example

If you don't set the random seed yourself, NetLogo sets it to a value based on the current date and time. There is no way to find out what random seed it chose, so if you want your model run to be reproducible, you must set the random seed yourself ahead of time.

The NetLogo primitives with "random" in their names (random, random-float, and so on) aren't the only ones that use pseudo-random numbers. Many other operations also make random choices. For example, agentsets are always in random order, one-of and n-of choose agents randomly, the sprout command creates turtles with random colors and headings, and the downhill reporter chooses a random patch when there's a tie. All of these random choices are governed by the random seed as well, so model runs can be reproducible.

In addition to the uniformly distributed random integers and floating point numbers generated by random and random-float, NetLogo also offers several other random distributions. See the dictionary entries for random-normal, random-poisson, random-exponential, and random-gamma.

Auxiliary generator

Code run by buttons or from the command center uses the main random number generator.

Code in monitors uses an auxiliary random generator, so even if a monitor does a calculation that uses random numbers, the outcome of the model is not affected. The same is true of code in sliders.

Local randomness

You may want to explicitly specify that a section of code does not affect the state of the main random generator, so the outcome of the model is not affected. The with-local-randomness command is provided for this purpose. See its entry in the NetLogo Dictionary for more information.

Turtle shapes

In NetLogo, turtle shapes are vector shapes. They are built up from basic geometric shapes; squares, circles, and lines, rather than a grid of pixels. Vector shapes are fully scalable and rotatable. NetLogo caches bitmap images of vector shapes size 1, 1.5, and 2 in order to speed up execution.

A turtle's shape is stored in its `shape` variable and can be set using the `set` command.

New turtles have a shape of "default". The `set-default-shape` primitive is useful for changing the default turtle shape to a different shape, or having a different default turtle shape for each breed of turtle.

The `shapes` primitive reports a list of currently available turtle shapes in the model. This is useful if, for example, you want to assign a random shape to a turtle:

```
ask turtles [ set shape one-of shapes ]
```

Use the Turtle Shapes Editor to create your own turtle shapes, or to add shapes to your model from our shapes library, or to transfer shapes between models. For more information, see the Shapes Editor section of this manual.

The thickness of the lines used to draw the vector shapes can be controlled by the `set-line-thickness` primitive.

Code Examples: Breeds and Shapes Example, Shape Animation Example

Link Shapes

Link Shapes are similar to turtle shapes, only you use the Link Shape Editor to create and edit them. Link shapes consist of between 0 and 3 lines which can have different patterns and a direction indicator that is composed of the same elements as turtle shapes. Links also have a `shape` variable that can be set to any link shape that is in the model. By default links have the "default" shape, though you can change that using `set-default-shape`. The `link-shapes` reporter reports all the link shapes included in the current model.

The thickness of the lines in the link shape is controlled by the `thickness` link variable.

Tick Counter

In many NetLogo models, time passes in discrete steps, called "ticks". NetLogo includes a built-in tick counter so you can keep track of how many ticks have passed.

The current value of the tick counter is shown above the view. (You can use the Settings button to hide the tick counter, or change the word "ticks" to something else.)

In code, to retrieve the current value of the tick counter, use the `ticks` reporter. The `tick` command advances the tick counter by 1. The `clear-all` command resets the tick counter to 0. If you want to reset the counter to 0 without clearing everything, use the `reset-ticks` command.

If your model is set to use tick-based updates, then the `tick` command will usually also update the view. See the next section, View Updates.

When to tick

We suggest using the `tick` command after your agents have completed all their movements and actions, but before you plot or calculate statistics. That way, if the plotting or calculating code refers to the tick counter, it will get the new value, reflecting that the tick is now complete. Example:

```
to go
  ask turtles [ move ]
  ask patches [ grow ]
  tick
  do-plots
end
to do-plots
  plotxy ticks count turtles
end
```

By putting `tick` before `do-plots`, the plotting code gets the right value of the tick counter when it uses the `ticks` reporter.

Fractional ticks

In most models, the tick counter starts at 0 and goes up 1 at a time, from integer to integer. But it's also possible for the tick counter to take on in-between floating point values.

To advance the tick counter by a fractional amount, use the `tick-advance` command. This command takes a numeric input specifying how far to advance the tick counter.

A typical use of fractional ticks is to approximate continuous or curved motion. See, for example, the GasLab models in the Models Library (under Chemistry & Physics). These models calculate the exact time at which a future event is to occur, then advance the tick counter to exactly that time.

View Updates

The "view" in NetLogo lets you see the agents in your model on your computer's screen. As your agents move and change, you see them moving and changing in the view.

Of course, you can't really see your agents directly. The view is a picture that NetLogo paints, showing you how your agents look at a particular instant. Once that instant passes and your agents move and change some more, that picture needs to be repainted to reflect the new state of the world. Repainting the picture is called "updating" the view.

When does the view get updated? This section discusses how NetLogo decides when to update the view, and how you can influence when it gets updated.

NetLogo offers two updates modes, "continuous" updates and "tick-based" updates. You can switch between NetLogo's two view update modes using a popup menu at the top of the Interface tab.

Continuous updates are the default when you start up NetLogo or start a new model. Nearly every model in our Models Library, however, uses tick-based updates.

Continuous updates are simplest, but tick−based updates give you more control over when and how often updates happen.

It's important exactly when an update happens, because when updates happen determines what you see on the screen. If an update comes at an unexpected time, you may see something unexpected −− perhaps something confusing or misleading.

It's also important how often updates happen, because updates take time. The more time NetLogo spends updating the view, the slower your model will run. With fewer updates, your model runs faster.

Continuous updates

Continuous updates are very simple. With continuous updates, NetLogo updates the view a certain number of times per second −− by default, 50 times a second when the speed slider is in the default, middle setting.

If you move the speed slider to a slower setting, NetLogo will update more than 50 times a second, effectively slowing down the model. On a faster setting, NetLogo will update less than 50 times a second. On the fastest setting, updates will be separated by several seconds.

At extremely slow settings, NetLogo will be updating so often that you will see your agents moving (or changing color, etc.) one at a time.

If you need to temporarily shut off continuous updates, use the `no−display` command. The `display` command turns updates back on, and also forces an immediate update (unless the user is fast−forwarding the model using the speed slider).

Tick−based updates

As discussed above in the Tick Counter section, in many NetLogo models, time passes in discrete steps, called "ticks". Typically, you want the view to update once per tick, between ticks. That's the default behavior with tick−based updates.

If you want additional view updates, you can force an update using the `display` command. (The update may be skipped if the user is fast−forwarding the model using the speed slider.)

You don't have to use the tick counter to use tick−based updates. If the tick counter never advances, the view will update only when you use the `display` command.

If you move the speed slider to a faster setting, NetLogo will skip some of the updates that would ordinarily have happened. Moving the speed slider to a slower setting doesn't cause additional updates; rather, it makes NetLogo pause after each update. The slower the setting, the longer the pause.

Even under tick−based updates, the view also updates whenever a button in the interface pops up (both once and forever buttons) and when a command entered in the Command Center finishes. So it's not necessary to add the `display` command to once buttons that don't advance the tick counter. Many forever buttons that don't advance the tick counter do need to use the `display` command. An example in the Models Library is the Life model (under Computer Science −> Cellular

Automata). The forever buttons that let the user draw in the view use the `display` command so the user can see what they are drawing, even though the tick counter is not advancing.

Choosing a mode

Advantages of tick−based updates over continuous updates include:

1. Consistent, predictable view update behavior which does not vary from computer to computer or from run to run.
2. Continuous updates can confuse the user of your model by letting them see model states they aren't supposed to see, which may be misleading.
3. Increased speed. Updating the view takes time, so if one update per tick is enough, then enforcing than there is only one update per tick will make your model faster.
4. Since `setup` buttons don't advance the tick counter, they are unaffected by the speed slider; this is normally the desired behavior.

As mentioned above, most models in our Models Library now uses tick−based updates.

Continuous updates are useful for models in which execution is not divided into short, discrete phases. An example in the Models Library is Termites. (See also, however, the State Machine Example model, which shows how to re−code Termites using ticks.)

Even for models that would normally be set to tick−based updates, it may be useful to switch to continuous updates temporarily for debugging purposes. Seeing what's going on within a tick, instead of only seeing the end result of a tick, could help with troubleshooting. After switching to continuous updates, you may want to use the speed slider to slow the model down until you see your agents moving one at a time. Don't forget to change back to tick−based updates when you are done, as the choice of update mode is saved with the model.

Plotting

NetLogo's plotting features let you create plots to help you understand what's going on in your model.

Before you can plot, you need to create one or more plots in the Interface tab. Each plot should have a unique name. You'll be using its name to refer to it in your code in the Procedures tab.

For more information on using and editing plots in the Interface tab, see the Interface Guide.

Specifying a plot

If you only have one plot in your model, then you can start plotting to it right away. But if you have more than one plot, you have to specify which one you want to plot to. To do this, use the `set−current−plot` command with the name of the plot enclosed in double quotes, like this:

```
set−current−plot "Distance vs. Time"
```

You must supply the name of the plot exactly as you typed it when you created the plot. Note that later if you change the name of the plot, you'll also have to update the `set−current−plot` calls in your model to use the new name. (Copy and paste can be helpful here.)

Specifying a pen

When you make a new plot, it just has one pen in it. If the current plot only has one plot pen, then you can start plotting to it right away.

But you can also have multiple pens in a plot. You can create additional pens by editing the plot and using the controls in the "Plot Pens" section at the bottom of the edit dialog. Each pen should have a unique name. You'll be using its name to refer to it in your code in the Procedures tab.

For a plot with multiple pens, you have to specify which pen you want to plot with. If you don't specify a pen, plotting will take place with the first pen in the plot. To plot with a different pen, use the `set-current-plot-pen` command with the name of the pen enclosed in double quotes, like this:

```
set-current-plot-pen "distance"
```

Plotting points

The two basic commands for actually plotting things are `plot` and `plotxy`.

With `plot` you need only specify the y value you want plotted. The x value will automatically be 0 for the first point you plot, 1 for the second, and so on. (That's if the plot pen's "interval" is the default value of 1; you can change the interval.)

The `plot` command is especially handy when you want your model to plot a new point at every time step. Example:

```
to setup
  ...
  plot count turtles
end

to go
  ...
  plot count turtles
end
```

Note that in this example we plot from both the "setup" and "go" procedures. That's because we want our plot to include the initial state of the system. We plot at the end of the "go" procedure, not the beginning, because we want the plot always to be up to date after the go button stops.

If you need to specify both the x and y values of the point you want plotted, then use `plotxy` instead.

Code Example: Plotting Example

Other kinds of plots

By default, NetLogo plot pens plot in line mode, so that the points you plot are connected by a line.

If you want to move the pen without plotting, you can use the `plot-pen-up` command. After this command is issued, the `plot` and `plotxy` commands move the pen but do not actually draw anything. Once the pen is where you want it, use `plot-pen-down` to put the pen back down.

If you want to plot individual points instead of lines, or you want to draw bars instead of lines or points, you need to change the plot pen's "mode". Three modes are available: line, bar, and point. Line is the default mode.

Normally, you change a pen's mode by editing the plot. This changes the pen's default mode. It's also possible to change the pen's mode temporarily using the `set-plot-pen-mode` command. That command takes a number as input: 0 for line, 1 for bar, 2 for point.

Histograms

A histogram is a special kind of plot that measures how frequently certain values, or values in certain ranges, occur in a collection of numbers that arise in your model.

For example, suppose the turtles in your model have an `age` variable. You could create a histogram of the distribution of ages among your turtles with the `histogram` command, like this:

```
histogram [age] of turtles
```

The numbers you want to histogram don't have to come from an agentset; they could be any list of numbers.

Note that using the `histogram` command doesn't automatically switch the current plot pen to bar mode. If you want bars, you have to set the plot pen to bar mode yourself. (As we said before, you can change a pen's default mode by editing the plot in the Interface tab.)

The width of the bars in a histogram is controlled by the plot pen's interval. You can set a plot pen's default interval by editing the plot in the Interface tab. You can also change the interval temporarily with the `set-plot-pen-interval` command or the `set-histogram-num-bars`. If you use the latter command, NetLogo will set the interval appropriately so as to fit the specified number of bars within the plot's current x range.

Code Example: Histogram Example

Clearing and resetting

You can clear the current plot with the `clear-plot` command, or clear every plot in your model with `clear-all-plots`. The `clear-all` command also clears all plots, in addition to clearing everything else in your model.

If you only want to remove only the points that the current plot pen has drawn, use `plot-pen-reset`.

When a whole plot is cleared, or when a pen is reset, that doesn't just remove the data that has been plotted. It also restores the plot or pen to its default settings, as they were specified in the Interface tab when the plot was created or last edited. Therefore, the effects of such commands as

`set-plot-x-range` and `set-plot-pen-color` are only temporary.

Autoplotting

By default, all NetLogo plots have the "autoplotting" feature enabled. This means that if the model tries to plot a point which is outside the current displayed range, the range of the plot will grow along one or both axes so that the new point is visible.

In the hope that the ranges won't have to change every time a new point is added, when the ranges grow they leave some extra room: 25% if growing horizontally, 10% if growing vertically.

If you want to turn off this feature, edit the plot and uncheck the Autoplot checkbox. At present, it is not possible to enable or disable this feature only on one axis; it always applies to both axes.

Temporary plot pens

Most plots can get along with a fixed number of pens. But some plots have more complex needs; they may need to have the number of pens vary depending on conditions. In such cases, you can make "temporary" plot pens from code and then plot with them. These pens are called "temporary" because they vanish when the plot is cleared (by the `clear-plot`, `clear-all-plots`, or `clear-all` commands).

To create a temporary plot pen, use the `create-temporary-plot-pen` command. Once the pen has been created, you can use it like any ordinary pen. By default, the new pen is down, is black in color, has an interval of 1, and plots in line mode. Commands are available to change all of these settings; see the Plotting section of the NetLogo Dictionary.

Using a Legend

You can show the legend of a plot by selecting the "Show legend" checkbox in the edit dialog. If you don't want a particular pen to show up in the legend you can uncheck the "Show in Legend" checkbox for that pen also in the edit dialog.

Conclusion

Not every aspect of NetLogo's plotting system has been explained here. See the Plotting section of the NetLogo Dictionary for information on additional commands and reporters related to plotting.

Many of the Sample Models in the Models Library illustrate various advanced plotting techniques. Also check out the following code examples:

Code Examples: Plot Axis Example, Plot Smoothing Example, Rolling Plot Example

Strings

To input a constant string in NetLogo, surround it with double quotes.

The empty string is written by putting nothing between the quotes, like this: `""`.

Most of the list primitives work on strings as well:

```
butfirst "string" => "tring"
butlast "string" => "strin"
empty? "" => true
empty? "string" => false
first "string" => "s"
item 2 "string" => "r"
last "string" => "g"
length "string" => 6
member? "s" "string" => true
member? "rin" "string" => true
member? "ron" "string" => false
position "s" "string" => 0
position "rin" "string" => 2
position "ron" "string" => false
remove "r" "string" => "sting"
remove "s" "strings" => "tring"
replace-item 3 "string" "o" => "strong"
reverse "string" => "gnirts"
```

A few primitives are specific to strings, such as `is-string?`, `substring`, and `word`:

```
is-string? "string" => true
is-string? 37 => false
substring "string" 2 5 => "rin"
word "tur" "tle" => "turtle"
```

Strings can be compared using the =, !=, <, >, <=, and >= operators.

If you need to embed a special character in a string, use the following escape sequences:

- `\n` = newline
- `\t` = tab
- `\"` = double quote
- `\\` = backslash

Output

This section is about output to the screen. Output to the screen can also be later saved to a file using the export-output command. If you need a more flexible method of writing data to external files, see the next section, File I/O.

The basic commands for generating output to the screen in NetLogo are print, show, type, and write. These commands send their output to the Command Center.

For full details on these four commands, see their entries in the NetLogo Dictionary. Here is how they are typically used:

- print is useful in most situations.
- show lets you see which agent is printing what.
- type lets you print several things on the same line.
- write lets you print values in a format which can be read back in using file-read.

A NetLogo model may optionally have an "output area" in its Interface tab, separate from the Command Center. To send output there instead of the Command Center, use the output−print, output−show, output−type, and output−write commands.

The output area can be cleared with the clear−output command and saved to a file with export−output. The contents of the output area will be saved by the export−world command. The import−world command will clear the output area and set its contents to the value in imported world file. It should be noted that large amounts of data being sent to the output area can increase the size of your exported worlds.

If you use output−print, output−show, output−type, output−write, clear−output, or export−output in a model which does not have a separate output area, then the commands apply to the output portion of the Command Center.

File I/O

In NetLogo, there is a set of primitives that give you the power to interact with outside files. They all begin with the prefix **file−**.

There are two main modes when dealing with files: reading and writing. The difference is the direction of the flow of data. When you are reading in information from a file, data that is stored in the file flows into your model. On the other hand, writing allows data to flow out of your model and into a file.

When a NetLogo model runs as an applet within a web browser, it will only be able to read data from files which are in the same directory on the server as the model file. Applets cannot write to any files.

When working with files, always begin by using the primitive `file−open`. This specifies which file you will be interacting with. None of the other primitives work unless you open a file first.

The next **file−** primitive you use dictates which mode the file will be in until the file is closed, reading or writing. To switch modes, close and then reopen the file.

The reading primitives include `file−read`, `file−read−line`, `file−read−characters`, and `file−at−end?` Note that the file must exist already before you can open it for reading.

Code Examples: File Input Example

The primitives for writing are similar to the primitives that print things in the Command Center, except that the output gets saved to a file. They include `file−print`, `file−show`, `file−type`, and `file−write`. Note that you can never "overwrite" data. In other words, if you attempt to write to a file with existing data, all new data will be appended to the end of the file. (If you want to overwrite a file, use `file−delete` to delete it, then open it for writing.)

Code Examples: File Output Example

When you are finished using a file, you can use the command file−close to end your session with the file. If you wish to remove the file afterwards, use the primitive file−delete to delete it. To close multiple opened files, one needs to first select the file by using file−open before closing it.

```
;; Open 3 files
file−open "myfile1.txt"
file−open "myfile2.txt"
file−open "myfile3.txt"

;; Now close the 3 files
file−close
file−open "myfile2.txt"
file−close
file−open "myfile1.txt"
file−close
```

Or, if you know you just want to close every file, you can use file−close−all.

Two primitives worth noting are file−write and file−read . These primitives are designed to easily save and retrieve NetLogo constants such as numbers, lists, booleans, and strings. file−write will always output the variable in such a manner that file−read will be able to interpret it correctly.

```
file−open "myfile.txt"  ;; Opening file for writing
ask turtles
  [ file−write xcor file−write ycor ]
file−close

file−open "myfile.txt"  ;; Opening file for reading
ask turtles
  [ setxy file−read file−read ]
file−close
```

Code Examples: File Input Example and File Output Example

Letting the user choose

The user−directory, user−file, and user−new−file primitives are useful when you want the user to choose a file or directory for your code to operate on.

Movies

This section describes how to capture a QuickTime movie of a NetLogo model.

First, use the movie−start command to start a new movie. The filename you provide should end with .mov, the extension for QuickTime movies.

To add a frame to your movie, use either movie−grab−view or movie−grab−interface, depending on whether you want the movie to show just the current view, or the entire Interface tab. In a single movie, you must use only one **movie−grab−** primitive or the other; you can't mix them.

When you're done adding frames, use movie−close.

```
;; export a 30 frame movie of the view
setup
movie-start "out.mov"
movie-grab-view ;; show the initial state
repeat 30
[ go
  movie-grab-view ]
movie-close
```

By default, a movie will play back at 15 frames per second. To make a movie with a different frame rate, call `movie-set-frame-rate` with a different number of frames per second. You must set the frame rate after `movie-start` but before grabbing any frames.

To check the frame rate of your movie, or to see how many frames you've grabbed, call `movie-status`, which reports a string that describes the state of the current movie.

To throw away a movie and delete the movie file, call `movie-cancel`.

Code Example: Movie Example

NetLogo movies are exported as uncompressed QuickTime files. To play a QuickTime movie, you can use QuickTime Player, a free download from Apple.

Since the movies are not compressed, they can take up a lot of disk space. You will probably want to compress your movies with third-party software. The software may give you a choice of different kinds of compression. Some kinds of compression are lossless, while others are lossy. "Lossy" means that in order to make the files smaller, some of the detail in the movie is lost. Depending on the nature of your model, you may want to avoid using lossy compression, for example if the view contains fine pixel-level detail.

One software package that can compress QuickTime movies on both the Mac and Windows platforms is QuickTime Pro. On Macs, iMovie works as well.

Perspective

The 2D and the 3D view show the world from the perspective of the observer. By default the observer is looking down on the world from the positive z-axis at the origin. You can change the perspective of the observer by using the `follow`, `ride` and `watch` observer commands and `follow-me`, `ride-me` and `watch-me` turtle commands. When in follow or ride mode the observer moves with the subject agent around the world. The difference between follow and ride is only visible in the 3D view. In the 3D view the user can change the distance behind the agent using the mouse. When the observer is following at zero distance from the agent it is actually riding the agent. When the observer is in watch mode it tracks the movements of one turtle without moving. In both views you will see a spotlight appear on the subject and in the 3D view the observer will turn to face the subject. To determine which agent is the focus you can use the `subject` reporter.

Code Example: Perspective Example

Drawing

The drawing is a layer where turtles can make visible marks.

In the view, the drawing appears on top of the patches but underneath the turtles. Initially, the drawing is empty and transparent.

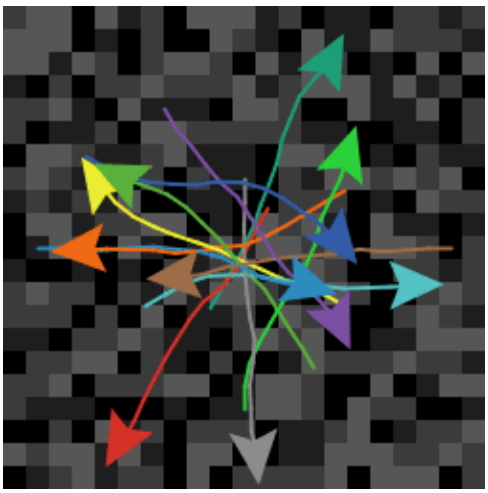
You can see the drawing, but the turtles (and patches) can't. They can't sense the drawing or react to it. The drawing is just for people to look at.

Turtles can draw and erase lines in the drawing using the `pen-down` and `pen-erase` commands. When a turtle's pen is down (or erasing), the turtle draws (or erases) a line behind it whenever it moves. The lines are the same color as the turtle. To stop drawing (or erasing), use `pen-up`.

Lines drawn by turtles are normally one pixel thick. If you want a different thickness, set the `pen-size` turtle variable to a different number before drawing (or erasing). In new turtles, the variable is set to 1.

Lines made when a turtle moves in a way that doesn't fix a direction, such as with `setxy` or `move-to`, the shortest path line that obeys the topology will be drawn.

Here's some turtles which have made a drawing over a grid of randomly shaded patches. Notice how the turtles cover the lines and the lines cover the patch colors. The `pen-size` used here was 2:



The `stamp` command lets a turtle leave an image of itself behind in the drawing and `stamp-erase` lets it remove the pixels below it in the drawing.

To erase the whole drawing, use the observer commmand `clear-drawing`. (You can also use `clear-all`, which clears everything else too.)

Importing an image

The observer command `import-drawing` command allows you to import an image file from disk into the drawing.

`import-drawing` is useful only for providing a backdrop for people to look at. If you want turtles and patches to react to the image, you should use `import-pcolors` or `import-pcolors-rgb` instead.

Comparison to other Logos

Drawing works somewhat differently in NetLogo than some other Logos.

Notable differences include:

- New turtles' pens are up, not down.
- Instead of using a `fence` command to confine the turtle inside boundaries, in NetLogo you edit the world and turn wrapping off.
- There is no `screen-color`, `bgcolor`, or `setbg`. You can make a solid background by coloring the patches, e.g. `ask patches [ set pcolor blue ]`.

Drawing features not supported by NetLogo:

- There is no `window` command. This is used in some other Logos to let the turtle roam over an infinite plane.
- There is no `flood` or `fill` command to fill an enclosed area with color.

Topology

The topology of the NetLogo world has four potential values, torus, box, vertical cylinder, or horizontal cylinder. The topology is controlled by enabling or disabling wrapping in the x or y directions. The default world is a torus, as were all NetLogo worlds before NetLogo 3.1.

A torus wraps in both directions, meaning that the top and bottom edges of the world are connected and the left and right edges are connected. So if a turtle moves beyond the right edge of the world it appears again on the left and the same for the top and bottom.

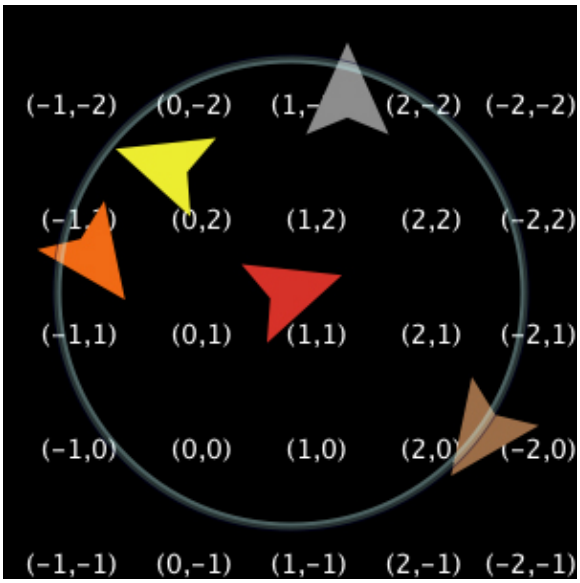
A box does not wrap in either direction. The world is bounded so turtles that try to move off the edge of the world cannot. Note that the patches around edge of the world have fewer than eight neighbors; the corners have three and the rest have five.

Horizontal and vertical cylinders wrap in one direction but not the other. A horizontal cylinder wraps vertically, so the top of the world is connected to the bottom. but the left and right edges are bounded. A vertical cylinder is the opposite; it wraps horizontally so the left and right edges are connected, but the top and bottom edges are bounded.

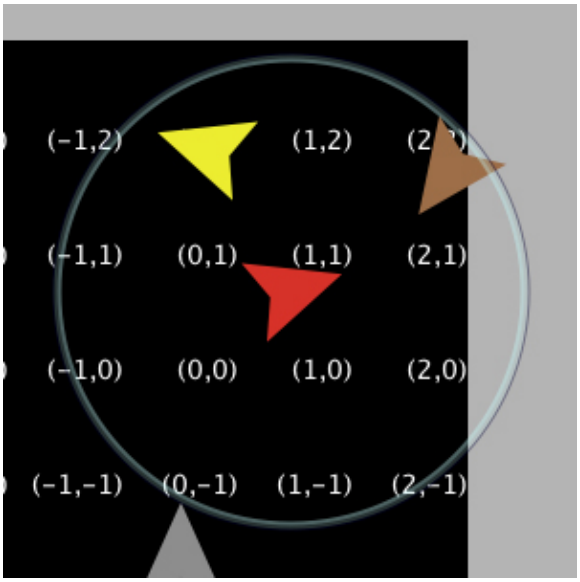
Code Example: Neighbors Example

Since NetLogo 3.0 there have been settings to enable wrapping visually, so if a turtle shape extends past an edge, part of the shape will appear on the other edge of the view. (Turtles themselves are points that take up no space, so they cannot be on both sides of the world at once, but in the view, they appear to take up space because they have a shape.)

Wrapping also affects how the view looks when you are following a turtle. On a torus, wherever the turtle goes, you will always see the whole world around it:



Whereas in a box or cylinder the world has edges, so the areas past those edges show up in the view as gray:



Code Example: Termites Perspective Demo (torus), Ants Perspective Demo (box)

Instead of 3.0's settings that only control the *appearance* of wrapping in the view, NetLogo 3.1 has settings that control whether the world *actually* wraps or not, that is, whether opposite edges are in fact connected. These new wrapping settings determine the world topology, that is, whether the world is a torus, box, or cylinder. This affects the behavior and not just the visual appearance of the model.

In the past, model authors were required to write extra code to simulate a box world, with the aid of special "no−wrap" primitives. No−wrap versions were provided for distance(xy), in−radius, in−cone, face(xy), and towards(xy). In 3.1 the special no−wrap versions are no longer necessary. Instead, the topology controls whether the primitives wrap or not. They always use the shortest path allowed by the topology. For example, the distance from the center of the patches in the bottom right corner (min−pxcor, min−pycor) and the upper left corner (max−pxcor, max−pycor) will be as follows for each topology given that the min and max pxcor and pycor are +/−2:

- Torus − sqrt(2) ~ 1.414 (this will be the same for all world sizes since the patches are directly diagonal to each other in a torus.)
- Box − sqrt(world−width^2 + world−height^2) ~ 7.07
- Vertical Cylinder − sqrt(world−height^2 + 1) ~ 5.099
- Horizontal Cylinder − sqrt(world−width^2 + 1) ~ 5.099

All the other primitives will act similarly to distance. If you formerly used no−wrap primitives in your model we recommend removing them and changing the topology of the world instead.

There are a number of reasons to change your model to use topologies rather than no−wrap primitives.

First, we expect if you are using no−wrap primitives, you are actually modeling a world that is not a torus. If you use a topology that matches the world you are modeling NetLogo does automatic bounds checking for you, it should make your life easier, your code simpler to understand and it adds visual cues to help the model user understand what you are modeling. Note that even with no−wrap primitives it was very difficult to model cylinders since the no−wrap primitives report the distance or heading when wrapping is not allowed in either direction.

You might have bugs in your model. If you are using a combination of no−wrap and wrap primitives, either it doesn't matter for some reason or there is a bug in your model (we found a few bugs in our models). For example, the Conductor model compared distance−no−wrap to distance to determine whether the next position is wrapped around the world, in which case the electron exits the system. This is a clever way to solve the problem, but unfortunately it is flawed. Electrons that wrap in the y direction were also exiting the system which is incorrect in this case. The only correct way to exit is to reach the cathode at the left end of the wire.

If you remove no−wrap commands the topology is no longer hard coded into the model so it's easier to test out your model on a different shape of world without a lot of extra coding (you may have to add a few extra checks to go from torus to box, this is explained more in−depth in the How to convert section.)

Note that though we've removed the no−wrap primitives from the dictionary they are still available for you to use; we did this so that old models don't have to be changed in order to run.

How to convert your model

When you first open up your model in 3.1 NetLogo will automatically change all cases of `( −screen−edge−x )` to `min−pxcor` and all cases of `screen−edge−x` to `max−pxcor` (and similarly for y) Though this is not directly related to the topology changes, you may also want to think about whether moving the origin off−center makes sense in your model at this time. Before NetLogo 3.1 the world had to be symmetrical around the origin, thus, the world had to have an odd width and height. This is no longer true since you may use any min and max combinations you wish,

given that the point (0,0) still exists in the world. If you are logically only modeling in one or two quadrants, or if it makes your code simpler to only use positive numbers you might want to consider changing your model. If you've modeled something that requires and even grid you'll certainly want to remove the programming hacks required to make that possible in the past.

Code Examples: Lattice Gas Automaton, Binomial Rabbits, Rugby

For NetLogo 3.1 we added new primitives which are essential if you change the topology, and quite convenient even if you don't. random−pxcor, random−pycor, random−xcor, and random−ycor report random values within the range between maximum and minimum (x and y). In older versions of NetLogo we often relied on wrapping to place turtles randomly across the world by writing `setxy random-float screen-size-x random-float screen-size-y`. However, if wrapping is not allowed in one direction or the other this no longer works (you get a runtime error for trying to place turtles outside the world). Regardless of topology, it is simpler and more straight forward to use `setxy random-xcor random-ycor` instead.

To convert a model to use a topology you must first decide what settings best describe the world. If the answer is not immediately obvious to you based on the real world, (a room is a box, a wire is a cylinder) there are a few clues that will help you. If anywhere in the code you are checking the bounds of the world or if some patches are not considered neighbors of the patches on the other side of the view it is likely that you are not using a torus. If you check bounds in both the x and y directions it's a box, in the x direction only, a horizontal cylinder, the y a vertical cylinder.

If you use no−wrap primitives you are probably not modeling a torus, however, be careful with this criterion if you use a mix of no−wrap and wrap primitives. It may be that you were using a no−wrap primitive for a visual element but the rest of the NetLogo world is still a torus.

After you've determined the topology and changed it by editing the view, you may have to make a few small changes to the code. If you've decided that the world is a torus you probably don't have to make any changes at all. If your model only uses patch neighbors and diffuse you probably will not need to make many changes.

If your model has turtles that move around your next step is to determine what happens to them when they reach the edge of the world. There are a few common options: the turtle is reflected back into the world (either systematically or randomly), the turtle exits the system (dies), or the turtle is hidden. It is no longer necessary to check the bounds using turtle coordinates, instead we can just ask NetLogo if a turtle is at the edge of the world. There are a couple ways of doing this, the simplest is to use the `can-move?` primitive.

```
if not can-move? distance [ rt 180 ]
```

can−move? merely returns true if the position *distance* in front of the turtle is inside the NetLogo world, false otherwise. In this case, if the turtle is at the edge of the world it simple goes back the way it came. You can also use `patch-ahead 1 != nobody` in place of `can-move?`. If you need to do something smarter that simply turning around it may be useful to use `patch-at` with `dx` and `dy`.

```
if patch-at dx 0 = nobody [
  set heading (- heading)
]
```

```
if patch-at 0 dy = nobody [
  set heading (180 - heading)
]
```

This tests whether the turtle is hitting a horizontal or vertical wall and bounces off that wall.

In some models if a turtle can't move forward it simply dies (exits the system, like in Conductor or Mousetraps).

```
if not can-move? distance[ die ]
```

If you are moving turtles using setxy rather than forward you should test to make sure the patch you are about to move to exists since setxy throws a runtime error if it is given coordinates outside the world. This is a common situation when the model is simulating an infinite plane and turtles outside the view should simply be hidden.

```
let new-x new-value-of-xcor
let new-y new-value-of-ycor

ifelse patch-at (new-x - xcor) (new-y - ycor) = nobody
  [ hide-turtle ]
  [ setxy new-x new-y
    show-turtle ]
```

Several models in the Models Library use this technique, Gravitation, N-Bodies, and Electrostatics are good examples.

By using a different topology you get diffuse for free (which was fairly difficult to do in the past). Each patch diffuses and equal amount of the diffuse variable to each of its neighbors, if it has fewer than 8 neighbors (or 4 if you are using diffuse4) the remainder stays on the diffusing patch. This means that the overall sum of patch-variable across the world remains constant. If you had special code to handle diffuse then you can remove it. However, if you want the diffuse matter to still fall off the edges of the world as it would on an infinite plane you still need to clear the edges each step as in the Diffuse Off Edges Example.

Links

A link is an agent that connects two turtles. The two turtles are called nodes. The link is always drawn as a line between the two turtles. Links do not have a location as turtles do, they are not considered to be on any patch and you cannot find the distance from a link to another point.

There are two flavors of links, undirected and directed. A directed link is *out* of, or *from*, one node and *in*to, or *to*, another node. The relationship of a parent to a child could be modeled as a directed link. An undirected link appears the same to both nodes, each node has a link *with* another node. The relationship between spouses, or siblings, could be modeled as an undirected link.

There is a global agentset of all links, just as with turtles and patches. You can create undirected links using the `create-link-with` and `create-links-with` commands; and directed links using the `create-link-to`, `create-links-to`, `create-link-from`, and `create-links-from` commands. Once the first link has been created directed or undirected, all unbreeded links must match (links also support breeds, much like turtles, which will be discussed shortly); it's impossible to have two unbreeded links where one is directed and the other is

undirected. A runtime error occurs if you try to do it. (If all unbreeded links die, then you can create links of that breed that are different in flavor from the previous links.)

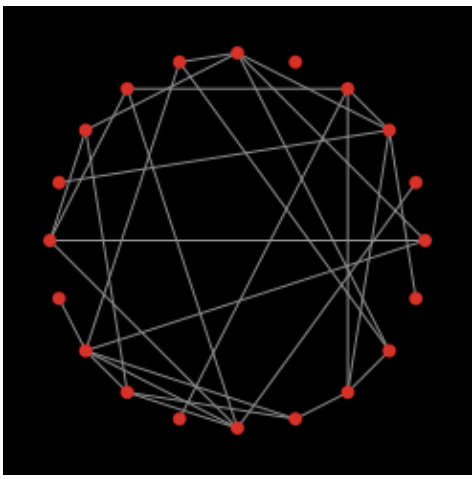
In general, primitives that work with directed links have "in", "out", "to", and "from" in their names. Undirected ones either omit these or use "with".

Link breeds, like turtle breeds, allow you to define different types of links in your model. Link breeds must either be directed or undirected, unlike unbreeded links this is defined at compile time rather than run time. You declare link breeds using the keywords `undirected-link-breed` and `directed-link-breed`. Breeded links can be created using the commands `create-<breed>-with` and `create-<breeds>-with` for undirected breeds and the commands `create-<breed>-to`, `create-<breeds>-to`, `create-<breed>-from`, and `create-<breeds>-from` for directed links.

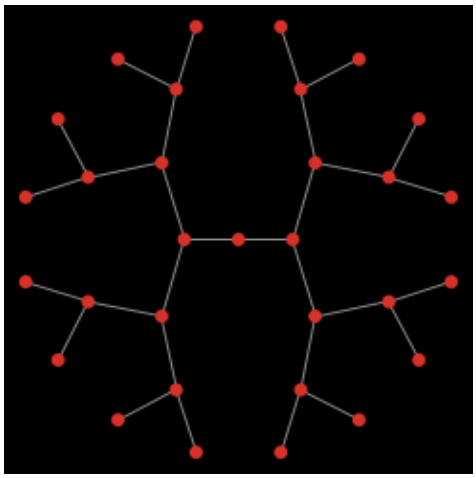
There cannot be more than one undirected link of the same breed (or two unbreeded links) between a pair of agents, nor more than one directed link of the same breed in the same direction between a pair of agents. You can have two directed links of the same breed (or two unbreeded links) between a pair if they are in opposite directions.

Layouts

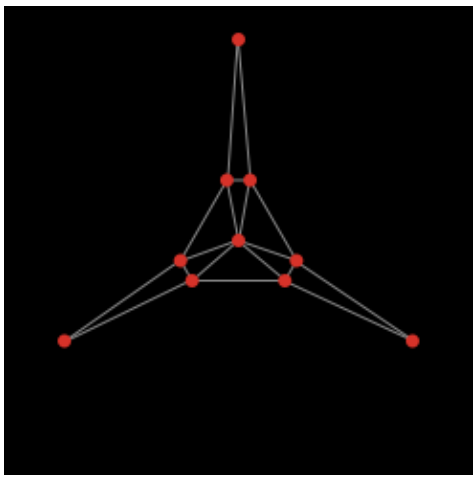
As part of the experimental network support we have also added several different primitives that will help you to visualize the networks. The simplest is `layout-circle` which evenly spaces the agents around the center of the world given a radius.



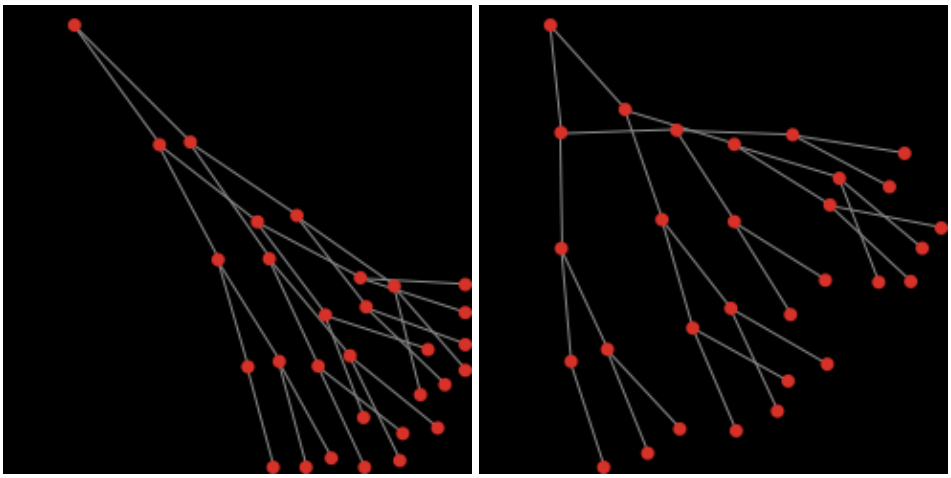
`layout-radial` is a good layout if you have something like a tree structure, though even if there are some cycles in the tree it will still work, though as there are more and more cycles it will probably not look as good. `layout-radial` takes a root agent to be the central node places it at (0,0) and arranges the nodes connected to it in a concentric pattern. Nodes one degree away from the root will be arranged in a circular pattern around the central node and the next level around those nodes and so on. `layout-radial` will attempt to account for asymmetrical graphs and give more space to branches that are wider. `layout-radial` also takes a breed as an input so you use one breed of links to layout the network and not another.



Given a set of anchor nodes `layout-tutte` places all the other nodes at the center of mass of the nodes it is linked to. The anchor set is automatically arranged in a circle layout with a user defined radius and the other nodes will converge into place (this of course means that you may have to run it several times before the layout is stable.)



`layout-spring` and `__layout-magspring` are quite similar and are useful for many kinds of networks. The drawback is that they are relatively slow since they take many iterations to converge. In both layouts the links act as springs that pull the nodes they connect toward each other and the nodes repel each other. In the magnetic spring there is also a magnetic field pulling the nodes in a compass direction you choose. The strength of all of these forces are controlled by inputs to the primitives. These inputs will always have a value between 0 and 1; keep in mind that very small changes can still affect the appearance of the network. The springs also have a length (in patch units), however, because of all the forces involved the nodes will not end up exactly that distance from each other. The magnetic spring layout also has a boolean input, bidirectional?, which indicates whether the springs should push in both directions parallel to the magnetic field; if it is true the networks will be more evenly spaced.



Code Examples: Network Example, Network Import Example, Giant Component, Small Worlds, Preferential Attachment

Ask−Concurrent

In previous versions of NetLogo, `ask` was concurrent by default. As of NetLogo 4.0, `ask` is serial, that is, the agents run the commands inside the ask one at a time.

The following information describes the behavior of the `ask-concurrent` command, which behaves the way the old `ask` behaved.

`ask-concurrent` produces simulated concurrency via a mechanism of turn−taking. The first agent takes a turn, then the second agent takes a turn, and so on until every agent in the asked agentset has had a turn. Then we go back to the first agent. This continues until all of the agents have finished running all of the commands.

An agent's "turn" ends when it performs an action that affects the state of the world, such as moving, or creating a turtle, or changing the value of a global, turtle, patch, or link variable. (Setting a local variable doesn't count.)

The `forward` (`fd`) and `back` (`bk`) commands are treated specially. When used inside `ask-concurrent`, these commands can take multiple turns to execute. During its turn, the turtle can only move by one step. Thus, for example, `fd 20` is equivalent to `repeat 20 [ fd 1 ]`, where the turtle's turn ends after each run of `fd`. If the distance specified isn't an integer, the last fraction of step takes a full turn. So for example `fd 20.3` is equivalent to `repeat 20 [ fd 1 ] fd 0.3`.

The `jump` command always takes exactly one turn, regardless of distance.

To understand the difference between `ask` and `ask-concurrent`, consider the following two commands:

```
ask turtles [ fd 5 ]
ask-concurrent turtles [ fd 5 ]
```

With `ask`, the first turtle takes ten steps forward, then the second turtle takes ten steps forward, and so on.

With `ask-concurrent`, all of the turtles take one step forward. Then they all take a second step, and so on. Thus, the latter command is equivalent to:

```
repeat 5 [ ask turtles [ fd 1 ] ]
```

> **Code Example:** Ask-Concurrent Example shows the difference between `ask` and `ask-concurrent`.

The behavior of `ask-concurrent` cannot always be so simply reproduced using `ask`, as in this example. Consider this command:

```
ask-concurrent turtles [ fd random 10 ]
```

In order to get the same behavior using `ask`, we would have to write:

```
turtles-own [steps]
ask turtles [ set steps random 10 ]
while [any? turtles with [steps > 0]] [
  ask turtles with [steps > 0] [
    fd 1
    set steps steps - 1
  ]
]
```

To prolong an agent's "turn", use the `without-interruption` command. (The command blocks inside some commands, such as `create-turtles` and `hatch`, have an implied `without-interruption` around them.)

Note that the behavior of `ask-concurrent` is completely deterministic. Given the same code and the same initial conditions, the same thing will always happen (if you are using the same version of NetLogo and begin your model run with the same random seed).

In general, we suggest you write your model so that it does not depend on the exact details of how `ask-concurrent` works. We make no guarantees that its semantics will remain the same in future versions of NetLogo.

Tie

Tie connects two turtles so that the movement of one turtles affects the location and heading of another. Tie is a property of links so there must be a link between two turtles to create a tie relationship.

When a link's `tie-mode` is set to "fixed" or "free" `end1` and `end2` are tied together. If the link is directed `end1` is the "root agent" and `end2` is the "leaf agent". That is when `end1` moves (using `fd`, `jump`, `setxy`, etc.) `end2` also moves the same distance and direction. However when `end2` moves it does not affect `end1`.

If the link is undirected it is a reciprocal tie relationship, meaning, if either turtle moves the other turtle will also move. So depending on which turtle is moving either turtle can be considered the root or the leaf. The root turtle is always the turtle that initiates the movement.

When the root turtle turns right or left, the leaf turtle rotates around the root turtle the same amount as if a stiff were attaching the turtles. When `tie-mode` is set to "fixed" the heading of the leaf turtle changes by the same amount. If the `tie-mode` is set to "free" the heading of the leaf turtle is unchanged.

The `tie-mode` of a link can be set to "fixed" using the `tie` command and set to "none" (meaning the turtles are no longer tied) using `untie` to set the mode to "free" you need to: `set tie-mode "free"`.

Code Example: Tie System Example

Syntax

This section contains technical terminology which will be unfamiliar to many readers.

Keywords

The only keywords in the language are `globals`, `breed`, `turtles-own`, `patches-own`, `to`, `to-report`, and `end`. (Built-in primitive names may not be shadowed or redefined, so they are effectively keywords as well.)

Identifiers

All primitives, global and agent variable names, and procedure names share a single global case-insensitive namespace; local names (`let` variables and the names of procedure inputs) may not shadow global names or each other. Identifiers may contain letters, digits, and the following ASCII characters:

```
[.?=*!<>:#+/%$_^'&-]
```

Non-ASCII characters are not currently allowed in identifiers. (We realize this is troublesome for international users and plan to address the issue in a future release.)

Some primitive names begin with two underscores to indicate that they are experimental and are especially likely to change or be removed in future NetLogo releases.

Identifiers beginning with a question mark are reserved.

Scope

NetLogo is lexically scoped. Local variables (including inputs to procedures) are accessible within the block of commands in which they are declared, but not accessible by procedures called by those commands.

Comments

The semicolon character introduces a comment, which lasts until the end of the line. There is no multi−line comment syntax.

Structure

A program consists of optional declarations (`globals`, `breed`, `turtles−own`, `patches−own`, `<BREED>−own`) in any order, followed by zero or more procedure definitions. Multiple breeds may be declared with separate `breed` declarations; the other declarations may appear once only.

Every procedure definition begins with `to` or `to−report`, the procedure name, and an optional bracketed list of input names. Every procedure definition ends with `end`. In between are zero or more commands.

Commands and reporters

Commands take zero or more inputs; the inputs are reporters, which may also take zero or more inputs. No punctuation separates or terminates commands; no punctuation separates inputs. Identifiers must be separated by whitespace or by parentheses or square brackets. (So for example, `a+b` is a single identifier, but `a(b[c]d)e` contains five identifiers.)

All commands are prefix. All user−defined reporters are prefix. Most primitive reporters are prefix, but some (arithmetic operators, boolean operators, and some agentset operators like with and in−points) are infix.

All commands and reporters, both primitive and user−defined, take a fixed number of inputs by default. (That's why the language can be parsed though there is no punctuation to separate or terminate commands and/or inputs.) Some primitives are variadic, that is, may optionally take a different number of inputs than the default; parentheses are used to indicate this, e.g. `(list 1 2 3)` (since the `list` primitive only takes two inputs by default). Parentheses are also used to override the default operator precedence, e.g. `(1 + 2) * 3`, as in other programming languages.

Sometimes an input to a primitive is a command block (zero or more commands inside square brackets) or a reporter block (a single reporter expression inside square brackets). User−defined procedures may not take a command or reporter block as input.

Operator precedences are as follows, high to low:

- `with`, `at−points`, `in−radius`, `in−cone`
- (all other primitives and user−defined procedures)
- `^`
- `*`, `/`, `mod`
- `+`, `−`
- `<`, `>`, `<=`, `>=`
- `=`, `!=`
- `and`, `or`, `xor`

Compared to other Logos

There is no agreed−upon standard definition of Logo; it is a loose family of languages. We believe that NetLogo has enough in common with other Logos to earn the Logo name. Still, NetLogo differs in some respects from most other Logos. The most important differences are as follows.

Surface differences

- The precedence of mathematical operators is different. Infix math operators (like +, *, etc.) have lower precedence than reporters with names. For example, in many Logos, if you write `sin x + 1`, it will be interpreted as `sin (x + 1)`. NetLogo, on the other hand, interprets it the way most other programming languages would, and the way the same expression would be interpreted in standard mathematical notation, namely as `(sin x) + 1`.
- The `and` and `or` reporters are special forms, not ordinary functions, and they "short circuit", that is, they only evaluate their second input if necessary.
- Procedures can only be defined in the Procedures tab, not interactively in the Command Center.
- Reporter procedures, that is, procedures that "report" (return) a value, must be defined with `to−report` instead of `to`. The command to report a value from a reporter procedure is `report`, not `output`.
- When defining a procedure, the inputs to the procedure must be enclosed in square brackets, e.g. `to square [x]`.
- Variable names are always used without any punctuation: always `foo`, never `:foo` or `"foo`. (To make this work, instead of a `make` command taking a quoted argument we supply a `set` special form which does not evaluate its first input.) As a result, procedures and variables occupy a single shared namespace.

The last three differences are illustrated in the following procedure definitions:

most Logos	NetLogo

`to square :x`
`output :x * :x`
`end`
	`to−report square [x]`
	`report x * x`
	`end`

Deeper differences

- NetLogo is lexically scoped, not dynamically scoped.
- NetLogo has no "word" data type (what Lisp calls "symbols"). Eventually, we may add one, but since it is seldom requested, it may be that the need doesn't arise much in agent−based modeling. We do have strings. In most situations where traditional Logo would use words, we simply use strings instead. For example in Logo you could write `[see spot run]` (a list of words), but in NetLogo you must write `"see spot run"` (a string) or `["see" "spot" "run"]` (a list of strings) instead.
- NetLogo's `run` command works on strings, not lists (since we have no "word" data type), and does not permit the definition or redefinition of procedures.
- Control structures such as `if` and `while` are special forms, not ordinary functions. You can't define your own special forms, so you can't define your own control structures. (NetLogo's `run` command is no help here.)
- As in most Logos, functions as values are not supported. Most Logos provide similar if less general functionality, though, by allowing passing and manipulation of fragments of source code in list form. NetLogo's capabilities in this area are presently limited. A few of our

built−in special forms use UCBLogo−style ``templates'' to accomplish a similar purpose, for example, `sort−by [length ?1 < length ?2] string−list`. In some circumstances, using `run` and `runresult` instead is workable, but unlike most Logos they operate on strings, not lists.

Of course, the NetLogo language also contains many additional features not found in most other Logos, most importantly agents and agentsets.

Transition Guide

Most models created in earlier versions of NetLogo also work in NetLogo 4.0. However, some models will need changes. If your old model isn't working, this section of the User Manual may be able to help you.

What issues you need to be aware of depends on how old your model is. The older the NetLogo version it was made with, the more issues you may need to be aware of.

This section does not list every change that was made for NetLogo 4.0. It discusses only the changes that are most likely to be issues for users. For a complete list of changes, see the What's New? section.

- Since NetLogo 3.1
- Since NetLogo 3.0

Since NetLogo 3.1

Who numbering

Prior to NetLogo 4.0, a dead turtle's who number (stored in the `who` turtle variable) could be reassigned to a later newborn turtle. In NetLogo 4.0, who numbers are never reused until who numbering is reset to 0 by the `clear-all` or `clear-turtles` command. This change in behavior may break a few old models.

Turtle creation: randomized vs. "ordered"

NetLogo 4.0 provides two different observer commands for creating turtles, `create-turtles` (`crt`) and `create-ordered-turtles` (`cro`).

`crt` gives the new turtles random colors and random integer headings. `cro` assigns colors sequentially and gives the turtles sequential equally spaced headings, with the first turtle facing north (heading of 0).

Prior to NetLogo 4.0, the `crt` command behaved the way `cro` does now. If your old model depends on the "ordered" behavior, you will need to change your code to use `cro` instead of `crt`.

It is common for old models that used `crt` to contain extra commands to randomize the new turtles' headings, for example `rt random 360` or `set heading random 360`. These commands are no longer necessary when used inside `crt`.

Adding strings and lists

Prior to NetLogo 4.0, the + (addition) operator could be used to concatenate strings and join lists. In current NetLogo, + only works on numbers. To concatenate strings, use the `word` primitive; to join lists together, use the `sentence` primitive. This language change was made to increase the speed of code that uses +.

Old code:

```
print "There are " + count turtles + " turtles."
```

New code:

```
print (word "There are " count turtles " turtles.")
```

Likewise, if you need to concatenate lists, use SENTENCE.

This change is not handled automatically when converting old models; users will need to change their code by hand.

We know this change will be awkward for users who are used to the old syntax. We have made this change for efficiency and consistency. A + operator that adds only numbers can be implemented much more efficiently than one that handles several different data types. Because addition is such a common operation, NetLogo's overall speed is affected.

Links

NetLogo 3.1 had supports for using links to connect turtles to make networks, graphs, and geometric figures. The links were themselves turtles.

In NetLogo 4.0, instead of links being turtles, links are now an independent fourth agent type, right alongside observer, turtles, patches. The primitives involving links are no longer considered experimental; they are now fully part of the language.

Models that use the old, experimental turtle−based link primitives will need to be updated to use link agents. The differences are not huge, but hand updating is required.

Links are documented in the Links section of the Programming Guide, and in the NetLogo Dictionary entries for the link primitives. See the Networks section of the Models Library for example models that use links. There are also some link−based Code Examples.

First you will need to remove any breeds called "links" if you are only using one type of links then you will not have to use breeds at all. If you are using multiple types of links see `undirected-link-breeds` and `directed-link-breeds`. Commands and reporters that contain the word "links" (like `__create-links-with`, etc.) will automatically be converted to the new form without underscores (`create-links-with`). However, primitives that use a different breed name (such as "edges") will not be converted. You will need to remove the underscores by hand and unless you are declaring a link breed with that name you will need to change the breed designation to "links".

The commands `remove-link(s)-with/from/to` no longer exist. Instead you should ask the links in question to `die`.

For example:

```
ask turtle 0 [ __remove-links-with link-neighbors ]
```

becomes

```
ask turtle 0 [ ask my-links [ die ] ]
```

Several of the layout commands have slightly different inputs, the first two inputs are generally a turtle agentset and a link agentset to perform the layout on. See the dictionary entries for details. layout-spring, layout-magspring layout-radial layout-tutte

You may also need to rearrange the declaration of turtles-own variables, since links were once actually turtles. Any variables that apply to links should be moved into a links-own block.

Since links are no longer turtles they no longer have the built-in turtle variables (though some of the link variables are the same such as color and label. If you formerly used the location of link turtles you will now need to calculate the midpoint of the link. This is fairly simple in a non-wrapping world.

```
to-report link-xcor
  report mean [xcor] of both-ends
end

to-report link-ycor
  report mean [ycor] of both-ends
end
```

it is a little bit trickier in a wrapping world but still fairly straight forward.

```
to-report link-xcor
  let other-guy end2
  let x 0
  ask end1
  [
    hatch 1
    [
      face other-guy
      fd [distance other-guy] of myself / 2
      set x xcor
      die
    ]
  ]
  report x
end
```

and similarly for ycor.

If you used either the size or heading of the link turtles you can use the reporters link-length and link-heading instead.

New "of" syntax

We have replaced three different language constructs, -of (with hyphen), value-from, and values-from with a single of construct (no hyphen).

old	new
color-of turtle 0	[color] of turtle 0
value-from turtle 0 [size * size]	[size * size] of turtle 0
mean values-from turtles [size]	mean [size] of turtles

When `of` is used with a single agent, it reports a single value. When used with an agentset, it reports a list of values (in random order, since agentsets are always in random order).

Note that when opening old models in the new version, `-of`, `value-from`, and `values-from` will automatically be converted to use "of" instead, but some nested uses of these constructs are too complex for the converter and must be converted by hand.

Serial `ask`

The `ask` command is now serial rather than concurrent. In other words, the asked agents will run one at a time. Not until one agent completely finishes the entire body of the `ask` does the next agent start.

Note that even the old `ask` was never truly concurrent; we simulated concurrent execution by interleaving execution among the agents using a turn-taking mechanism described in the NetLogo FAQ.

We have made this change because in our experience, users often wrote models that behaved in unexpected ways due to the simulated concurrency, but rarely wrote models that benefited from the simulated concurrency. Models exhibiting unexpected behavior could usually be fixed by adding the `without-interruption` command in the right places, but it was difficult for users to know whether that command was needed and if so, where.

In NetLogo 4.0, `without-interruption` is no longer necessary unless your model uses `ask-concurrent` (or a turtle or patch forever button containing code that depends on simulated concurrency). In most models, all uses of `without-interruption` can be removed.

The simulated concurrency formerly employed by "ask" is still accessible in three ways:

- You may use the `ask-concurrent` primitive instead of `ask` to get the old simulated concurrency
- Commands issued in the Command Center directly to turtles, patches, or links have an implied `ask-concurrent`.
- Turtle, patch, and link forever buttons have an implied `ask-concurrent` as well.

Note that `ask` itself is always serial regardless of the context in which it is used, however.

In our own Models Library, models that make use of this concurrency are rare. A prominent example, though, is Termites, which uses a concurrent turtle forever button.

Tick counter

NetLogo now has a built-in tick counter for representing the passage of simulated time.

You advance the counter by one using the `tick` command. If you need to read its value, there's a reporter called `ticks`. The `clear-all` command resets the tick counter; so does `reset-ticks`.

In most models the tick counter will be integer-valued, but if you want to use smaller increments of time, you can use the `tick-advance` command to advance the tick counter by any positive amount, including fractional amounts. Some Models Library models that use `tick-advance` are

Vector Fields and the GasLab models.

The value of the tick counter is displayed in the toolbar at the top of the Interface tab. (You can use the Settings... button in the toolbar to hide the tick counter, or change the word "ticks" to something else.)

View update modes

In the past, NetLogo always tried to update the view about 20 times a second. We're now calling that "continuous" view updates. The biggest problem with it was that you usually want updates to happen between model ticks, not in the middle of a tick, so we had a checkbox on buttons that (by default) forced a display update after every button iteration. That made sure updates happened between ticks, but it didn't get rid of the intermediate updates. You had to use `no-display` and `display` to lock them out.

We still support continuous updates. They are the default when you start up NetLogo. But most Models Library models now use tick-based updates. With tick-based updates, updates happen only when the tick counter advances. (The `display` command can be used to force additional updates; see below.)

The advantages of tick-based updates as we see them are as follows:

1. Consistent, predictable view update behavior which does not vary from computer to computer or from run to run.
2. Intermediate updates can confuse the user of your model by letting them see things they aren't supposed to see, which may be misleading.
3. Increased speed. Updating the view takes time, so if one update per tick is enough, then enforcing than there is only one update per tick will make your model faster.
4. Instead of having a "force view update" checkbox in every button like in NetLogo 3.1, we only need one choice which applies to the entire model.
5. Using the speed slider to slow down a model now just inserts pauses between ticks. So with tick-based updates, `setup` buttons are no longer affected by the speed slider. This was a real annoyance with the old speed slider. (The annoyance persists for models that use continuous updates, though.)

As mentioned above, most models in our Models Library now uses tick-based updates.

Even for models that would normally be set to tick-based updates, it may be useful to switch to continuous updates temporarily for debugging purposes. Seeing what's going on within a tick, instead of only seeing the end result of a tick, could help with troubleshooting.

If you switch your model to use tick-based updates, you'll also need to add the `tick` command to your code, otherwise the view won't update. (Note that the view still always updates when a button pops up or a command entered in the command center finishes, though. So it's not like the view will just stay frozen indefinitely.)

How to make a model use ticks and tick-based updates

Here are the steps to follow to convert your model to use ticks and tick-based updates in NetLogo 4.0:

1. In the Interface tab toolbar, on the right hand side where it says "update view:", change the setting from "continuously" to "on ticks".
2. Add the `tick` command to your go procedure, at or near the end. In Models Library models we always put `tick` after the agents move but before any plotting commands. That's because the plotting commands might contain something like `plotxy ticks ...` and we want the new value of the tick counter used, not the old one. Most models don't refer to the tick counter in their plotting commands, but nonetheless, for consistency and to avoid mistakes we suggest always putting `tick` before the plotting commands.

Some models will require some additional changes:

1. If your model already has a global "ticks" or "clock" or "time" variable, get rid of it. Use the `tick` command and `ticks` reporter instead. (If your model uses fractional increments of time, use `tick-advance` instead of `tick`.) If you had a monitor for that variable, you can get rid of it; there's now a tick counter in the toolbar.
2. `clear-all` resets the tick counter to zero. If you don't use `clear-all` in your setup procedure, then you may need to add `reset-ticks` to reset the counter to zero.
3. If you used `no-display` and `display` to prevent view updates from happening in the middle of go, you can get rid of them.
4. If your model needs to update the view without advancing the tick counter (examples: Party, Dice Stalagmite, network models with animated layout, models with mouse interaction buttons), use the `display` command to force additional view updates so the user can see what is going on.

Speed slider

Previous versions of NetLogo had a speed slider that could be used to make models run slower, so you can see what's going on.

In NetLogo 4.0, the slider can be used to speed up models as well. It does this by updating the view less frequently. Updating the view takes time, so the fewer updates, the faster the model runs.

The default position of the slider is in the center. When you're at the center, the slider says "normal speed".

As you move the slider away from the center position, the model will gradually run faster or slower.

At very high speeds, view updates become very infrequent and may be separated by several seconds. It may feel like the model is actually running slower, since the updates are so infrequent. But watch the tick counter, or other indicators such as plots, and you'll see that yes, the model really is running faster. If the infrequent updates are disconcerting, don't push the slider so far over.

When using tick-based updates, slowing the model down does not cause additional view updates. Rather, NetLogo simply pauses after each tick.

When using continuous updates, slowing the model down means view updates become more closely spaced. If you push the speed slider more than halfway to the left, the model will be running so slowly that you can watch turtles moving one at a time! This is new in NetLogo 4.0; in previous NetLogo versions, no matter how slowly you ran a model, you would never see the agents in an `ask` moving one at a time; all the agents in an `ask` always appeared to move together.

Numbers

NetLogo no longer maintains an internal distinction between integers and floating point numbers. So for example:

Old:

```
observer> print 3
3
observer> print 3.0
3.0
observer> print 1 + 2
3
observer> print 1.5 + 1.5
3.0
observer> print 3 = 3.0
true
```

(The last line shows that although the distinction between integer 3 and floating point 3.0 was maintained, the two numbers were still considered equal.)

New:

```
observer> print 3
3
observer> print 3.0
3
observer> print 1 + 2
3
observer> print 1.5 + 1.5
3
observer> print 3 = 3.0
true
```

We expect that only rare models will be negatively impacted by this change.

A benefit of this change is that NetLogo now supports a much larger range of integers. The old range was −2,147,483,648 to 2,147,483,647 (around +/− 2 billion); the new range is +/−9,007,199,254,740,992 (around +/− 9 quadrillion).

Agentset building

NetLogo 3.1 (and some earlier versions) included primitives called `turtles-from` and `patches-from` that were occasionally useful for building agentsets. In NetLogo 4.0, these primitives have been replaced with new primitives called `turtle-set` and `patch-set` that are much more flexible and powerful. (`link-set` exists as well.) See the entries for these primitives in the NetLogo Dictionary. Models that use the old `turtles-from` and `patches-from` will need to be altered by hand to use the new primitives.

RGB Colors

In NetLogo 3.1 RGB and HSB colors could be approximated as NetLogo colors using the `rgb` and `hsb` primitives. These have been renamed to approximate-rgb and `approximate-hsb` and now expect inputs in the range 0−255, not 0−1.

The full RGB spectrum is now available in NetLogo so it may no longer be necessary to use these primitives at all. You can set any color variable to a three−item RGB list, with values in the 0−255 range, and get that exact color. See the Color section of the Programming Guide for details.

Tie

In previous versions `__tie` was provided as an experimental feature. As of NetLogo 4.0 links have a `tie-mode` variable which can be set to `"none"`, `"free"`, or `"fixed"`. In 4.0 `tie` is now a link−only primitive. This means that to tie two turtle 1 to turtle 0 you write:

```
ask turtle 0 [ create-link-to turtle 1 [ tie ] ]
```

See the Tie section of the programming guide for details.

HubNet Clients

A HubNet activity's client interface is no longer stored in a separate model file. To import a client from an old model select File −> Import −> Import HubNet Client. Then when asked, import from the Interface Tab. You will no longer need the external client model and you will no longer need to point to it when setting the client interface so this:

```
hubnet-set-client-interface "COMPUTER" [ "my-client.nlogo" ]
```

becomes:

```
hubnet-set-client-interface "COMPUTER" []
```

Performance of Lists

The internal implementation of lists has changed which changes some of the performance properties of lists, see the Programming guide for details on the current implementation. Note that `fput` is much faster than `lput` thus, you may improve performance simply by switching to `fput`. If performance is still a problem you may want to consider using the Array &Table extensions

Since NetLogo 3.0

Agentsets

If your model is behaving strangely or incorrectly, perhaps it's because since NetLogo 3.1, agentsets are now always in random order. In prior versions of NetLogo, agentsets were always in a fixed order. If your code depended on that fixed order, then it won't work anymore. How to fix your model to work with randomized agentsets depends on the details of what your code is doing. In some situations, it is helpful to use the `sort` or `sort-by` primitives to convert an agentset (random order) into a list of agents (fixed order). See "Lists of agents" in the Lists section of the Programming Guide.

Wrapping

If you are seeing pieces of turtle shapes wrapping around the view edges, it's because NetLogo 3.0

allowed you to turn off such wrapping in the view without affecting the behavior of the model. Since NetLogo 3.1, if you don't want the view to wrap you must make it so the world doesn't wrap, using the new topology feature. Making this change may require other changes to your model, though. See the Topology section of the Programming Guide for a thorough discussion of how to convert your model to take advantage of this new feature.

Applets

Individual models can be run as Java applets inside a web browser.

Making and Displaying Applets

You can create applets by choosing the Save As Applet option from the File Menu. If your model is not saved in it's current state you will be prompted to save it again, you will also be prompted to have an html file.

For applets to work, the html file, your model file, and the file NetLogoLite.jar must all be in the same directory. (You can copy NetLogoLite.jar from the directory where you installed NetLogo.)

Applets can read and write files on the web server. If your applet requires additional files, files it reads from, imported images, etc. You will also need to upload those files to the server. These files should appear in the same directory configuration relative to the model file as they appear on your computer. Applets cannot read or write files on the user's computer, only the web server. Applets cannot browse web server or the user's computer, meaning, that `user-file` and `user-new-file` do nothing in an applet. All files required to run your model including the model file itself and NetLogoLite.jar must be readable by the web server user.

On some systems, you can test the applet locally on your computer before uploading it to a web server. It doesn't work on all systems, though, so if it doesn't work from your hard drive, please try uploading it to a web server.

You don't need to include everything in the html file in your page. If you want, you can just take the HTML code beginning with <applet> and ending with </applet>, and paste it into any HTML file you want. It's even OK to put multiple <applet> tags on a single page.

If NetLogoLite.jar and your model are in different directories, you must modify the archive= and value= lines in the HTML code to point to their actual locations. (For example, if you have multiple applets in different directories on the same web server, you may want to put a single copy of NetLogoLite.jar in one central place and change the archive= lines of all the HTML files to point to that one central copy. This will save disk space for you and download time for your users.)

Java Requirements

Getting the right version

Current versions of NetLogo require that your web browser support Java 1.4.1 or higher. Here's how to get the right Java:

- If you're on Windows 98 or newer, you need to download the Java browser plugin from http://www.java.com/en/download/windows_manual.jsp.
- If you're on Mac OS X, you need OS X 10.2.6 or higher. If you're on OS X 10.2, you also need Java 1.4.1 Update 1, which is available through Software Update. OS X 10.3 and higher already has the right Java. You must also use a web browser that supports Java 1.4. Internet Explorer does not work; Safari does.

- If you're on Windows 95, MacOS 8, or MacOS 9, running models over the web is no longer supported; you must download the NetLogo 1.3.1 application and run the models that way instead.
- If you're on Linux or another Unix, you will need version 1.4.1 or higher of the Sun Java Runtime Environment. It is available for download at http://www.java.com/. Check your browser's home page for information about installing the Java plugin.

If you think you have the right browser and plugin, but it still doesn't work, check your browser's preferences to make sure that Java is enabled.

The following web site may be helpful for figuring out what Java you have and getting the right version running: http://www.javatester.org/.

Increasing the available memory

Some NetLogo applets may require more memory than the browser normally makes available. This may happen if you have large numbers of agents. On Windows, you can increase the available memory ("heap") space in the Java Control Panel's applet runtime settings.

Mac users, note that Mac OS X 10.2 and 10.3 had a fairly low memory limit for Java applets, namely 64 megabytes. Historically Mac OS X 10.4 had the same limit, but a recent Java update raised it to 96 megabytes. You can get the Java update from Apple through Software Update. Mac OS X 10.5 will presumably have the higher limit as well.

If your browser is using the browser plug−in that comes with the **Sun JDK or JRE** then instructions for starting the **Java Plug−In Control Panel** are available here. In the *Advanced* tab of the Control Panel add the following to the *Java Runtime Parameters* field: "−Xms16M −Xmx1024M".

Extensions

Many extensions can be used in applets, simply upload the directory containing the extension jar into the same directory as the model.

Extensions that require additional external jars don't work from applets. This includes the sound and gogo extensions.

Known Issues

- Extensions that require external jars don't work from applets.
- the 3D view does not work in applets.
- the code generator is not used in applets (which means that models will run somewhat slower)
- web servers that return custom error messages may cause java exceptions. See the FAQ for the workaround.

Shapes Editor Guide

The Turtle and Link Shape Editors allows you to create and save turtle and link designs. NetLogo uses fully scalable and rotatable vector shapes, which means you can create designs by combining basic geometric elements, which can appear on−screen in any size or orientation.

Getting Started

To begin making shapes, choose **Turtle Shapes Editor** or **Link Shapes Editor** in the Tools menu. A new window will open listing all the shapes currently in the model, beginning with *default*, the default shape. The Shapes Editor allows you to edit shapes, create new shapes, and borrow from another model. You can also import turtle shapes from a library of pre−existing shapes.

Importing Shapes

Every new model in NetLogo starts off containing a small core set of frequently used shapes. Many more turtle shapes are available by using the **Import from library...** button. This brings up a dialog where you can select one or more shapes and bring them into your model. Select the shapes, then press the **Import** button.

Similarly, you can use the **Import from model...** button to borrow shapes from another model.

Default shapes

Here are the turtle shapes that are included by default in every new NetLogo model:

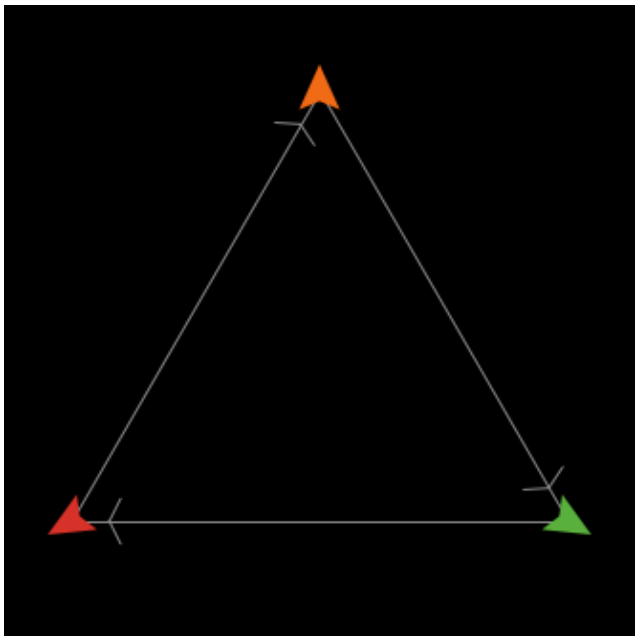
First row: default, airplane, arrow, box, bug, butterfly
Second row: car, circle, circle 2, cow, cylinder, dot
Third row: face happy, face neutral, face sad, fish, flag, flower

Fourth row: house, leaf, line, line half, pentagon, person
Fifth row: plant, square, square 2, star, target, tree
Sixth row: triangle, triangle 2, truck, turtle, wheel, x

Shapes library

And here are the shapes in the shapes library (including all of the default shapes, too):

By default there is only one Link shape in a model, that is "default". This shape is simply a single straight line with a simple arrowhead (if the link happens to be directed).



Creating and Editing Turtle Shapes

Pressing the **New** button will make a new shape. Or, you may select an existing shape and press **Edit**.

Tools

In the upper left corner of the editing window is a group of drawing tools. The arrow is the selection tool, which selects an already drawn element.

To draw a new element, use one of the other seven tools:

- The **line** tool draws line segments.
- The **circle**, **square**, and **polygon** tools come in two versions, solid and outline.

When using the polygon tool, click the mouse to add a new segment to the polygon. When you're done adding segments, double click.

After you draw a new element, it is selected, so you can move, delete, or reshape it if you want:

- To move it, drag it with the mouse
- To delete it, press the Delete button.
- To reshape it, drag the small "handles" that appear on the element only when it is selected.
- To change its color, click on the new color.

Previews

As you draw your shape, you will also see it in five smaller sizes in the five preview areas found near the bottom of the editing window. The previews show your shape as it might appear in your model, including how it looks as it rotates. The number below each preview is the size of the preview in pixels. When you edit the view, patch size is also measured in pixels. So for example, the preview with "20" below it shows you how your shape would look on a turtle (of size 1) on patches of size 20 pixels.

The rotatable feature can be turned off if you want a shape that always faces the same way, regardless of the turtle's heading.

Overlapping Shapes

New elements go on top of previous elements. You can change the layering order by selecting an element and then using the **Bring to front** and **Send to back** buttons.

Undo

At any point you can use the **Undo** button to undo the edit you just performed.

Colors

Elements whose color matches the *Color that changes* (selected from a drop−down menu −− the default is gray) will change color according to the value of each turtle's *color* variable in your model. Elements of other colors don't change. For example, you could create cars that always have yellow headlights and black wheels, but different body colors.

Other buttons

The "Rotate Left" and "Rotate Right" buttons rotate elements by 90 degrees. The "Flip Horizontal" and "Flip Vertical" buttons reflect elements across the axes.

These four buttons will rotate or flip the entire shape, unless an element is selected, in which case only that element is affected.

These buttons are especially handy in conjunction with the "Duplicate" button if you want to make shapes that are symmetrical. For example, if you were making a butterfly, you could draw the butterfly's left wing with the polygon tool, then duplicate the wing with the "Duplicate" button, then turn the copy into a right wing with the "Flip Horizontal" button.

Shape Design

It's tempting to draw complicated, interesting shapes, but remember that in most models, the patch size is so small that you won't be able to see very much detail. Simple, bold, iconic shapes are usually best.

Keeping a Shape

When the shape is done, give it a name and press the **Done** button at the bottom of the editing window. The shape and its name will now be included in the list of shapes along with the "default" shape.

Creating and Editing Link Shapes

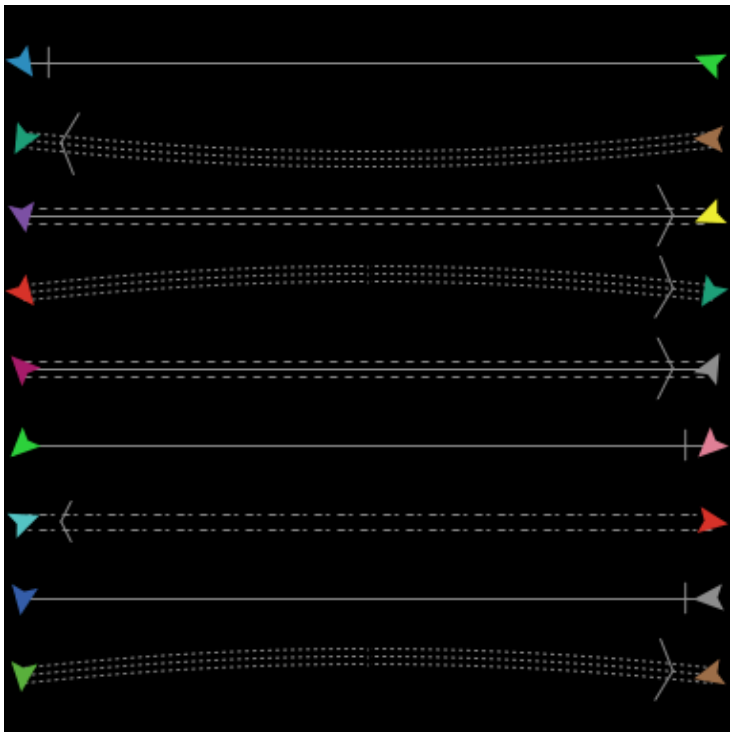
Managing link shapes is very similar to managing turtle shapes. So, you can create a new shape but pressing the **New** button or you can edit existing shapes, when you are done editing a shape press **Done** if you want to keep it.

Changing Link Shape Properties

There are several different properties for each link shape that you are allowed to change:

- Name − link shapes can have the same name as turtle shapes but must be unique among link shapes.
- Direction Indicator − the direction indicator (the little arrow on directed links) is just like the turtle vector shapes, you can edit it using the same editor by pressing the **Edit** button.
- Curviness − this is the amount of bend in a link expressed in patches (this is particularly useful if you have directed links going in both directions so you can discern both links)
- Number of lines: You can have 1, 2, or 3 lines in each link shape, you control this by selecting line patterns in the "left line", "middle line", and "right line" selection boxes.
- Dash pattern of lines: There are several dashed line patterns available in the selection boxes so not all lines need be solid.

Here are a few link shapes with various properties:



Using Shapes in a Model

In the model's code or in the command center, you can use any of the shapes that are in the model (though only turtles can have turtle shapes and only links can have link shapes) For example, suppose you want to create 50 turtles with the shape "rabbit". Provided there is some turtle shape called *rabbit* in this model, give this command to the observer in the command center:

```
observer> crt 50
```

And then give these commands to the turtles to spread them out, then change their shape:

```
turtles> fd random 15
turtles> set shape "rabbit"
```

Voila! Rabbits! Note the use of double quotes around the shape name. Shape names are strings.

Similarly, you can set the shape variable of links. Assuming there is a link shape called "road" in this model:

```
observer> crt 5 [ create-links-with other turtles ]
turtles> fd 5
links> set shape "road"
```

The `set-default-shape` command is also useful for assigning shapes to turtles and links.

BehaviorSpace Guide

This guide has three parts:

- **What is BehaviorSpace?**: A general description of the tool, including the ideas and principles behind it.
- **How It Works**: Walks you through how to use the tool and highlights its most commonly used features.
- **Advanced Usage**: How to use BehaviorSpace from the command line, or from your own Java code.

What is BehaviorSpace?

BehaviorSpace is a software tool integrated with NetLogo that allows you to perform experiments with models. It runs a model many times, systematically varying the model's settings and recording the results of each model run. This process is sometimes called "parameter sweeping". It lets you explore the model's "space" of possible behaviors and determine which combinations of settings cause the behaviors of interest.

Why BehaviorSpace?

The need for this type of experiment is revealed by the following observations. Models often have many settings, each of which can take a range of values. Together they form what in mathematics is called a parameter space for the model, whose dimensions are the number of settings, and in which every point is a particular combination of values. Running a model with different settings (and sometimes even the same ones) can lead to drastically different behavior in the system being modeled. So, how are you to know which particular configuration of values, or types of configurations, will yield the kind of behavior you are interested in? This amounts to the question of where in its huge, multi−dimension parameter space does your model perform best?

For example, suppose you want speedy synchronization from the agents in the Fireflies model. The model has four sliders −− number, cycle−length, flash−length and number−flashes −− that have approximately 2000, 100, 10 and 3 possible values, respectively. That means there are 2000 * 100 * 10 * 3 = 600,000 possible combinations of slider values! Trying combinations one at a time is hardly an efficient way to learn which one will evoke the speediest synchronization.

BehaviorSpace offers you a much better way to solve this problem. If you specify a subset of values from the ranges of each slider, it will run the model with each possible combination of those values and, during each model run, record the results. In doing so, it samples the model's parameter space −− not exhaustively, but enough so that you will be able to see relationships form between different sliders and the behavior of the system. After all the runs are over, a dataset is generated which you can open in a different tool, such as a spreadsheet, database, or scientific visualization application, and explore.

By enabling you to explore the entire "space" of behaviors a model can exhibit, BehaviorSpace can be a powerful assistant to the modeler.

Historical Note

Old versions of NetLogo (prior to 2.0) included an earlier version of the BehaviorSpace tool. That version was much different. It wasn't nearly as flexible in the kinds of experiments it let you set up. But, it had facilities for display and analyzing experiment results that are missing from the current version. With the current version, it is assumed that you will use other software to analyze your results. We hope to re−add data display and analysis facilities to a future version of BehaviorSpace.

How It Works

To begin using BehaviorSpace, open your model, then choose the BehaviorSpace item on NetLogo's Tools menu.

Managing experiment setups

The dialog that opens lets you create, edit, duplicate, delete, and run experiment setups. Experiments are listed by name and how by model runs the experiment will consist of.

Experiment setups are considered part of a NetLogo model and are saved as part of the model.

To create a new experiment setup, press the "New" button.

Creating an experiment setup

In the new dialog that appears, you can specify the following information. Note that you don't always need to specify everything; some parts can be left blank, or left with their default values, depending on your needs.

Experiment name: If you have multiple experiments, giving them different names will help you keep them straight.

Vary variables as follows: This is where you specify which settings you want varied, and what values you want them to take. Variables can include sliders, switches, choosers, and any global variables in your model.

Variables can also include `max−pxcor`, `min−pxcor`, `max−pycor` and `min−pycor`, `world−width`, `world−height` and `random−seed`. These are not, strictly speaking, variables, but BehaviorSpace lets you vary them as if they were. Varying the world dimensions lets you explore the effect of world size upon your model. Since setting `world−width` and `world−height` does not necessarily define the bounds of the world how they are varied depends on the location of the origin. If the origin is centered, BehaviorSpace will keep it centered so the values `world−width` or `world−height` must be odd. If one of the bounds is at zero that bound will be kept at zero and the other bound will move, for example if you start with a world with `min−pxcor` = 0 `max−pxcor` = 10 and you vary `world−width` like this:

```
["world−width" [11 1 14]]
```

`min-pxcor` will stay at zero and `max-pxcor` will set to 11, 12, and 13 for each of the runs. If neither of these conditions are true, the origin is not centered, nor at the edge of the world you cannot vary `world-height` or `world-width` directly but you should vary `max-pxcor`, `max-pycor`, `min-pxcor` and `min-pycor` instead.

Varying `random-seed` lets you repeat runs by using a known seed for the NetLogo random number generator. Note that you're also free to use the `random-seed` command in your experiment's setup commands. For more information on random seeds, see the Random Numbers section of the Programmer's Guide.

You may specify values either by listing the values you want used, or by specifying that you want to try every value within a given range. For example, to give a slider named `number` every value from 100 to 1000 in increments of 50, you would enter:

```
["number" [100 50 1000]]
```

Or, to give it only the values of 100, 200, 400, and 800, you would enter:

```
["number" 100 200 400 800]
```

Be careful with the brackets here. Note that there are fewer square brackets in the second example. Including or not including this extra set of brackets is how you tell BehaviorSpace whether you are listing individual values, or specifying a range.

Also note that the double quotes around the variable names are required.

You can vary as many settings as you want, including just one, or none at all. Any settings that you do not vary will retain their current values. Not varying any settings is useful if you just want to do many runs with the current settings.

What order you list the variables in determines what order the runs will be done in. All values for a later variable will be tried before moving to the next value for an earlier variable. So for example if you vary both x and y from 1 to 3, and x is listed first, then the order of model runs will be: x=1 y=1, x=1 y=2, x=1 y=3, x=2 y=1, and so on.

Repetitions: Sometimes the behavior of a model can vary a lot from run to run even if the settings don't change, if the model uses run numbers. If you want to run the model more than once at each combination of settings, enter a higher number here than one.

Measure runs using these reporters: This is where you specify what data you want to collect from each run. For example, if you wanted to record how the population of turtles rose and fell during each run, you would enter:

```
count turtles
```

You can enter one reporter, or several, or none at all. If you enter several, each reporter must be on a line by itself, for example:

```
count frogs
count mice
count birds
```

If you don't enter any reporters, the runs will still take place. This is useful if you want to record the results yourself your own way, such as with the `export-world` command.

Measure runs at every step: Normally NetLogo will measure model runs at every step, using the reporters you entered in the previous box. If you're doing very long model runs, you might not want all that data. Uncheck this box if you only want to measure each run after it ends.

Setup commands: These commands will be used to begin each model run. Typically, you will enter the name of a procedure that sets up the model, typically `setup`. But it is also possible to include other commands as well.

Go commands: These commands will be run over and over again to advance to the model to the next "step". Typically, this will be the name of a procedure, such as `go`, but you may include any commands you like.

Stop condition: This lets you do model runs of varying length, ending each run when a certain condition becomes true. For example, suppose you wanted each run to last until there were no more turtles. Then you would enter:

```
not any? turtles
```

If you want the length of runs to all be of a fixed length, just leave this blank.

The run may also stop because the go commands use the `stop` command, in the same way that `stop` can be used to stop a forever button. The `stop` command may be used directly in the go commands, or in a procedure called directly by the go commands. (The intent is that the same `go` procedure should work both in a button and in a BehaviorSpace experiment.) Note that the step in which `stop` is used is considered to have been aborted, so no results will be recorded for that step. Therefore, the stopping test should be at the beginning of the go commands or procedure, not at the end.

Final commands: These are any extra commands that you want run once, when the run ends. Usually this is left blank, but you might use it to call the `export-world` command or record the results of the run in some other way.

Time limit: This lets you set a fixed maximum length for each run. If you don't want to set any maximum, but want the length of the runs to be controlled by the stop condition instead, enter 0.

Running an experiment

When you're done setting up your experiment, press the "OK" button, followed by the "Run" button.

You will be prompted to select the formats you would like the data from your experiment saved in. Data is collected for each interval, run or step, according to the setting of **Measure runs at every step** option.

Table format lists each interval in a row, with each metric in a separate column. Table data is written to the output file as each run completes. Table format is suitable for automated processing of the data, such as importing into a database or a statistics package.

Spreadsheet format calculates the min, mean, max, and final values for each metric, and then lists each interval in a row, with each metric in a separate column. Spreadsheet data is more human−readable than Table data, especially if imported into a spreadsheet application.

(Note however that spreadsheet data is not written to the results file until the experiment finishes. Since spreadsheet data is stored in memory until the experiment is done, very large experiments could run out of memory. And if anything interrupts the experiment, such as a runtime error, running out of memory, or a crash or power outage, no results will be written. For long experiments, you may want to use both spreadsheet and table formats so that if something happens you'll at least get a table of partial results.)

After selecting your output formats, BehaviorSpace will prompt you for the name of a file to save the results to. The default name ends in ".csv". You can change it to any name you want, but don't leave off the ".csv" part; that indicates the file is a Comma Separated Values (CSV) file. This is a plain−text data format that is readable by any text editor as well as by most popular spreadsheet and database programs.

A dialog will appear, titled "Running Experiment". In this dialog, you'll see a progress report of how many runs have been completed so far and how much time has passed. If you entered any reporters for measuring the runs, and if you left the "Measure runs at every step" box checked, then you'll see a plot of how they vary over the course of each run.

You can also watch the runs in the main NetLogo window. (If the "Running Experiment" dialog is in the way, just move it to a different place on the screen.) The view and plots will update as the model runs. If you don't need to see them update, then use the checkboxes in the "Running Experiment" dialog to turn the updating off. This will make the experiment go faster.

If you want to stop your experiment before it's finished, press the "Abort" button. But note that you'll lose any results that were generated in the spreadsheet format up to that point. Table results are written as the experiment runs and will not be lost.

When all the runs have finished, the experiment is complete.

Advanced usage

Running from the command line

It is possible to run BehaviorSpace experiments "headless", that is, from the command line, without any graphical user interface (GUI). This is useful for automating runs on a single machine or a cluster of machines.

No Java programming is required. Experiment setups can be created in the GUI and then run later from the command line, or, if you prefer, you can create or edit experiment setups directly using XML.

It is easiest if you create your experiment setup ahead of time in the GUI, so it is saved as part of the model. To run an experiment setup saved in a model, here is an example command line:

```
java -server -Xms16M -Xmx1024M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment1
```

(For this to work, `NetLogo.jar` must be present along with the `lib` subdirectory containing necessary libraries. Both `NetLogo.jar` and `lib` are included with NetLogo.)

After the named experiment has run, the results are sent to standard output in spreadsheet format, as CSV. (To change this, see below.)

When running the HeadlessWorkspace class as an application, it forces the system property `java.awt.headless` to be true. This tells Java to run in headless mode, allowing NetLogo to run on machines when a graphical display is not available.

Note the user of the `-server` flag to tell Java to optimize performance for "server" type applications; we recommend this flag for best performance in most situations.

Note the use of `-Xmx` to specify a maximum heap size of one gigabyte. If you don't specify a maximum heap size, you will get your VM's default size, which may be unusably small. (One gigabyte is an arbitrary size which should be more than large enough for most models; you can specify a different limit if you want.) Note also that `-Xms` is used to specify a larger-than-default initial heap size. This helps some models run faster by making garbage collection more efficient.

The `--model` argument is used to specify the model file you want to open.

The `--experiment` argument is used to specify the name of the experiment you want to run. (At the time you create an experiment setup in the GUI, you assign it a name.)

Here's another example that shows some additional, optional arguments:

```
java -server -Xms16M -Xmx1024M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment2 \
  --max-pxcor 100 \
  --min-pxcor -100 \
  --max-pycor 100 \
  --min-pycor -100 \
  --no-results
```

Note the use of the optional `--max-pxcor`, `--max-pycor`, etc. arguments to specify a different world size than that saved in the model. (It's also possible for the experiment setup to specify values for the world dimensions; if they are specified by the experiment setup, then there is no need to specify them on the command line.)

Note also the use of the optional `--no-results` argument to specify that no output is to be generated. This is useful if the experiment setup generates all the output you need by some other means, such as exporting world files or writing to a text file.

Yet another example:

```
java -server -Xms16M Xmx1024M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment2 \
  --table table-output.csv \
  --spreadsheet spreadsheet-output.csv
```

The optional `--table <filename>` argument specifies that output should be generated in a table format and written to the given file as CSV data. If - is specified as the filename, than the output is sent to the standard system output stream. Table data is written as it is generated, with each complete run.

The optional `--spreadsheet <filename>` argument specified that spreadsheet output should be generated and written to the given file as CSV data. If - is specified as the filename, than the output is sent to the standard system output stream. Spreadsheet data is not written out until all runs in the experiment are finished.

Note that it is legal to specify both `--table` and `--spreadsheet`, and if you do, both kinds of output file will be generated.

The default output behavior, when no output formats are specified, is to send table output to the system standard output stream.

Here is one final example that shows how to run an experiment setup which is stored in a separate XML file, instead of in the model file:

```
java -server -Xms16M -Xmx1024M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --setup-file fire-setups.xml \
  --experiment experiment3
```

If the XML file contains more than one experiment setup, it is necessary to use the `--experiment` argument to specify the name of the setup to use.

The next section has information on how to create standalone experiment setup files using XML.

Setting up experiments in XML

We don't yet have detailed documentation on authoring experiment setups in XML, but if you already have some familiarity with XML, then the following pointers may be enough to get you

started.

The structure of BehaviorSpace experiment setups in XML is determined by a Document Type Definition (DTD) file. The DTD is stored in NetLogo.jar, as `system/behaviorspace.dtd`. (JAR files are also zip files, so you can extract the DTD from the JAR using Java's "jar" utility or with any program that understands zip format.)

The easiest way to learn what setups look like in XML, though, is to author a few of them in BehaviorSpace's GUI, save the model, and then examine the resulting .nlogo file in a text editor. The experiment setups are stored towards the end of the .nlogo file, in a section that begins and ends with a `experiments` tag. Example:

```
<experiments>
  <experiment name="experiment" repetitions="10" runMetricsEveryStep="true">
    <setup>setup</setup>
    <go>go</go>
    <exitCondition>not any? fires</exitCondition>
    <metric>burned-trees</metric>
    <enumeratedValueSet variable="density">
      <value value="40"/>
      <value value="0.1"/>
      <value value="70"/>
    </enumeratedValueSet>
  </experiment>
</experiments>
```

In this example, only one experiment setup is given, but you can put as many as you want between the beginning and ending `experiments` tags.

Between looking at the DTD, and looking at examples you create in the GUI, it will hopefully be apparent how to use the tags to specify different kind of experiments. The DTD specifies which tags are required and which are optional, which may be repeated and which may not, and so forth.

When XML for experiment setups is included in a model file, it does not begin with any XML headers, because not the whole file is XML, only part of it. If you keep experiment setups in their own file, separate from the model file, then the extension on the file should be .xml not .nlogo, and you'll need to begin the file with proper XML headers, as follows:

```
<?xml version="1.0" encoding="us-ascii"?>
<!DOCTYPE experiments SYSTEM "behaviorspace.dtd">
```

The second line must be included exactly as shown. In the first line, you may specify a different encoding than `us-ascii`, such as `UTF-8`, but NetLogo doesn't support non-ASCII characters in most situations, so specifying a different encoding may be pointless.

Controlling API

If BehaviorSpace is not sufficient for your needs, a possible alternative is to use our Controlling API, which lets you write Java code that controls NetLogo. The API lets you run BehaviorSpace experiments from Java code, or, you can write custom code that controls NetLogo more directly to do BehaviorSpace-like things. See the Controlling section of the User Manual for further details on both possibilities.

Conclusion

BehaviorSpace is still under development. We'd like to hear from you about what what additional features would be useful to you in your work. Please write us at feedback@ccl.northwestern.edu.

HubNet Guide

This section of the User Manual introduces the HubNet system and includes instructions to set up and run a HubNet activity.

HubNet is a technology that lets you use NetLogo to run *participatory simulations* in the classroom. In a participatory simulation, a whole class takes part in enacting the behavior of a system as each student controls a part of the system by using an individual device, such as a networked computer or Texas Instruments graphing calculator.

For example, in the Gridlock simulation, each student controls a traffic light in a simulated city. The class as a whole tries to make traffic flow efficiently through the city. As the simulation runs, data is collected which can afterwards be analyzed on a computer or calculator.

For more information on participatory simulations and their learning potential, please visit the Participatory Simulations Project web site.

Understanding HubNet

NetLogo

NetLogo is a programmable modeling environment. It comes with a large library of existing simulations, both participatory and traditional, that you can use and modify. Content areas include social science and economics, biology and medicine, physics and chemistry, and mathematics and computer science. You and your students can also use it to build your own simulations. For more about NetLogo, see the NetLogo Users Manual.

In traditional NetLogo simulations, the simulation runs according to rules that the simulation author specifies. HubNet adds a new dimension to NetLogo by letting simulations run not just according to rules, but by direct human participation.

Since HubNet builds upon NetLogo, we recommend that before trying HubNet for the first time, you become familiar with the basics of NetLogo. To get started using NetLogo models, see Tutorial #1: Running Models in the NetLogo Users Manual.

HubNet Architecture

HubNet simulations are based on a client−server architecture. The activity leader uses the NetLogo application to run a HubNet activity. When NetLogo is running a HubNet activity, we refer to it as a HubNet server. Participants use a client application to log in and interact with the HubNet server.

There are two types of HubNet available. With Computer HubNet, participants run the HubNet Client application on computers connected by a regular computer network. In Calculator HubNet, created in conjunction with Texas Instruments, participants use Texas Instruments graphing calculators as clients which communicate via the TI−Navigator system.

We hope to add support for other types of clients such as cell phones and PDA's (Personal Digital Assistants).

Computer HubNet

Activities

The following activities are available in the Models Library, in the Computer HubNet Activities folder. For many models, you will find a discussion of its educational goals and suggested ways to incorporate it into your classroom in the Participatory Simulations Guide on the Participatory Simulations Project web site. More information can also be found in the Information Tab in each model.

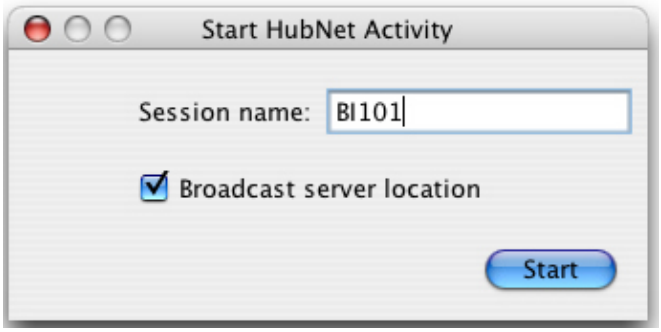
- Disease −− A disease spreads through the simulated population of students.
- Gridlock −− Students use traffic lights to control the flow of traffic through a city.
- Polling −− Ask students questions and plot their answers.
- Tragedy of the Commons −− Students work as farmers sharing a common resource.

Requirements

To use Computer HubNet, you need a networked computer with NetLogo installed for the activity leader, and a networked computer with NetLogo installed for each participant. We also suggest an attached projector for the leader to project the entire simulation to the participants.

Starting an activity

You'll find the HubNet activities in NetLogo's Models Library, in the HubNet Computer Activities folder. We suggest doing a few practice runs of an activity before trying it in front of a class.

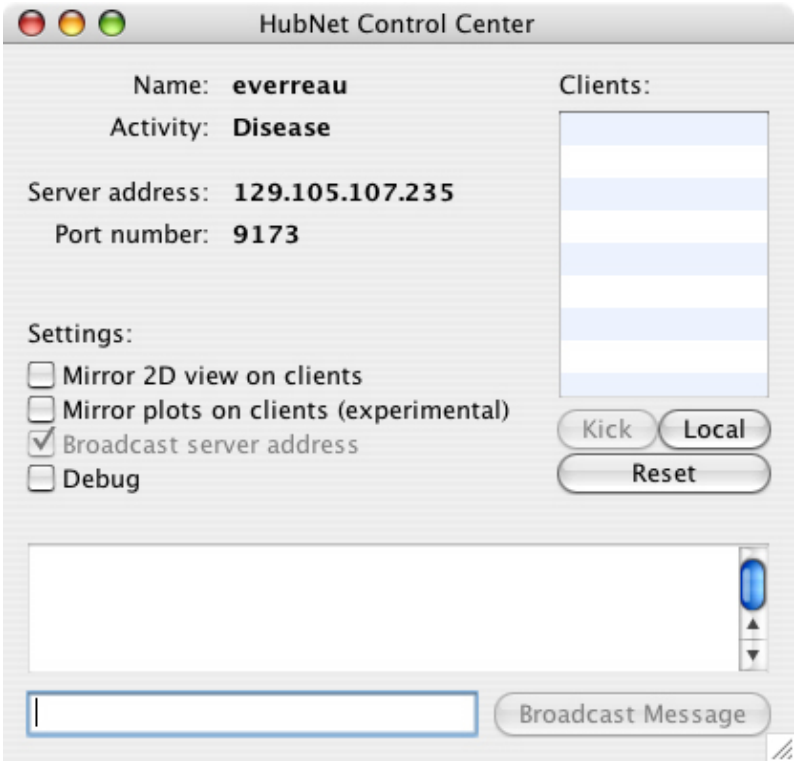


Open a Computer HubNet model. NetLogo will prompt you to enter the name of your new HubNet session. This is the name that participants will use to identify this activity. Enter a name and press Start.

NetLogo will open the HubNet Control Center, which lets you interact with the HubNet server.

You, as the leader, should then notify everyone that they may join. To join the activity, participants launch the HubNet Client application and enter their name. They should see your activity listed and can join your activity by selecting it and pressing Enter. If the activity you started is not listed the student can enter the server address manually which can be found in the HubNet Control Center.

HubNet Control Center



The HubNet Control Center lets you interact with the HubNet server. It displays the name, activity, address and port number of your server. The "Mirror 2D View on clients" checkbox controls whether the HubNet participants can see the view on their clients, assuming there is a view in the client setup. The "Mirror plots on clients" checkbox controls whether participants will receive plot information.

The client list on the right displays the names of clients that are currently connected to you activity. To remove a participant from the activity, select their name in the list and press the Kick button. To launch your own HubNet client press the Local button, this is particularly useful when you are debugging an activity. The "Reset" button kicks out all currently logged in clients and reloads the client interface.

The lower part of the Control Center displays messages when a participant joins or leaves the activity. To broadcast a message to all the participants, click on the field at the bottom, type your message and press Broadcast Message.

Troubleshooting

I started a HubNet activity, but when participants open a HubNet Client, my activity isn't listed.

On some networks, the HubNet Client cannot automatically detect a HubNet server. Tell your participants to manually enter the server address and port of your HubNet server, which appear in the HubNet Control Center.

Note: The technical details on this are as follows. In order for the client to detect the server, multicast routing must be available between them. Not all networks support multicast routing. In particular, networks that use the IPsec protocol typically do not support multicast. The IPsec protocol is used on many virtual private networks (VPNs).

When a participant tries to connect to an activity, nothing happens (the client appears to hang or gives an error saying that no server was found).

If your computer or network has a firewall, it may be impeding the HubNet server from communicating. Make sure that your computer and network are not blocking ports used by the HubNet server (ports 9173−9180).

The view on the HubNet client is grey.

- Verify that the "Mirror 2D view on clients" checkbox in the HubNet Control Center is selected.
- Make sure that the display switch in the model is on.
- If you have made changes to the size of the view on the server you may need to press the "Reset" button in the Control Center to ensure the clients get the new size.

There is no view on the HubNet client.

Some activities don't have a view on the client. If you want to add a view simply select "HubNet Client Editor" from the Tools Menu and add a view like any other widget. Make sure to press the "Reset" button before having clients log in.

I can't quit a HubNet client.

You will have to force the client to quit. On OS X, force quit the application by selecting Force Quit... in the Apple menu. On Windows, press Ctrl−Alt−Delete to open the Task Manager, select HubNet Client and press End Task.

My computer went to sleep while running a HubNet activity. When I woke the computer up, I got an error and HubNet wouldn't work anymore.

The HubNet server may stop working if the computer goes to sleep. If this happens, quit the NetLogo application and start over. Change the settings on your computer so it won't sleep again.

My problem is not addressed on this page.

Please send us an email at feedback@ccl.northwestern.edu.

Known Limitations

If HubNet malfunctions, please send us an email at bugs@ccl.northwestern.edu.

Please note that:

- HubNet has not yet been extensively tested with large numbers of clients (i.e. more than about 25). Unexpected results may occur with more clients.

- Out−of−memory conditions are not handled gracefully
- Sending large amounts of plotting messages to the clients can take a long time.
- NetLogo does not handle malicious clients in a robust manner (in other words, it is likely vulnerable to denial−of−service type attacks).
- Performance does not degrade gracefully over slow or unreliable network connections.
- If you are on a wireless network or sub−LAN, the IP address in the HubNet Control Center is not always the entire IP address of the server.
- Computer HubNet has only been tested on LANs, and not on dial−up connections or WANs.

Calculator HubNet

Calculator HubNet for TI−Navigator

The TI−Navigator Classroom Learning System is a wireless classroom network for TI graphing calculators. TI−Navigator users can install a free NetLogo extension, which integrates with TI−Navigator and allows the calculators to act as clients for participatory simulations like the ones that are available for Computer HubNet. The Calculator HubNet extension is available from Inquire Learning, LLC, in collaboration with Texas Instruments. Inquire Learning also offers support, curricular materials, and professional development for the Calculator HubNet system. For more information on the TI−Navigator system itself, please visit the Texas Instruments website, at http://education.ti.com/navigator. For more information on the Calculator HubNet extension for TI−Navigator, please contact Inquire Learning, at calc−hubnet@inquirelearning.com, or visit http://www.inquirelearning.com/calc−hubnet.html.

Teacher workshops

For information on upcoming workshops and NetLogo and HubNet use in the classroom, please contact us at feedback@ccl.northwestern.edu.

HubNet Authoring Guide

To learn about authoring or modifying HubNet activities, see the HubNet Authoring Guide.

Getting help

If you have any questions about Computer HubNet or Calculator HubNet, or need help getting started, please email us at feedback@ccl.northwestern.edu.

HubNet Authoring Guide

This guide presents information you will need to understand and modify the code of existing HubNet Activities as well as write your own HubNet activities. This guide assumes you are familiar with running HubNet activities, basic NetLogo code and NetLogo interface elements, for more general information about HubNet see the HubNet Guide.

- General HubNet Information
- Coding HubNet Activities
  - Setup
  - Receiving information from clients
  - Sending information to clients
- Calculator HubNet Information
- Computer HubNet Information
  - How To Make a Client Interface
  - View Updates on the Clients
  - Clicking in the View on Clients
  - Plot Updates on the Clients

General HubNet Information

The information presented in this section is specifically targeted at those using computer clients, however, much of the code presented can be reused with small modifications to use calculator clients.

Coding HubNet Activities

Many HubNet Activities will share bits of the same code. That is the code that it used to setup the network and the code that is used to receive information from and send information to the clients. If you understand this code you should be able to easily make modifications to existing activities and you should have a good start on writing your own activities. To get you started we have provided a Template model (in HubNet Computer Activities −> Code Examples) that contains the most basic components that will be in the majority of HubNet Activities. You should be able to use this activity as a starting point for most projects.

Setup

To make a NetLogo model into a HubNet activity you must first initialize the network. In most HubNet activities you will use the `startup` procedure to initialize the network `Startup` is a special procedure, NetLogo will try to run the `startup` procedure when you open any model. That makes it a good place to put code that you want to run once and only once (no matter how many times the user runs the model). For HubNet we put the commands that initialize the network in `startup` because once the network is setup we don't need to do so again. First specify the type of clients using `hubnet-set-client-interface`, in this case we will be using computer clients:

```
hubnet-set-client-interface "COMPUTER" []
```

Then initialize the system using `hubnet-reset`, which will ask the user for a session name and open up the HubNet Control Center. NetLogo is now ready to start listening for client messages.

Now that the network is all setup you don't need to worry about calling `hubnet-set-client-interface` or `hubnet-reset` again. Take a look at the setup procedure in the template model:

```
to setup
  cp
  cd
  clear-output
  ask turtles
  [
    set step-size 1
    hubnet-send user-id "step-size" step-size
  ]
end
```

For the most part it looks like most other setup procedures, however, you should notice that it does not call `clear-all`. In this model, and in the great majority of HubNet activities in the Models Library, we have a breed of turtles that represent the currently logged in clients. In this case we've called this breed `students`. Whenever a client logs in we create a student and record any information we might need later about that client in a turtle variable. Since we don't want to require users to log out and log back in every time we setup the activity we don't want to kill all the turtles, instead, we want to set all the variables back to initial values and notify the clients of any changes we make (more on that later).

Receiving messages from clients

During the activity you will be transferring data between the HubNet clients and the server. Most HubNet activities will call a procedure in the `go` loop that checks for new messages from clients in this case it's called listen clients:

```
to listen-clients
  while [ hubnet-message-waiting? ]
  [
    hubnet-fetch-message
    ifelse hubnet-enter-message?
    [ create-new-student ]
    [
      ifelse hubnet-exit-message?
      [ remove-student ]
      [ execute-command hubnet-message-tag ]
    ]
  ]
end
```

As long as there are messages in the queue this loop fetches each message one at a time. `hubnet-fetch-message` makes the next message in the queue the current message and sets the reporters `hubnet-message-source`, `hubnet-message-tag`, and `hubnet-message` to the appropriate values. The clients send messages when the users login and logout any time the user manipulates one of the interface elements, that is, pushes a button, moves a slider, clicks in the view, etc. We step through each message and decide what action to take depending on the type of message (enter, exit, or other), the `hubnet-message-tag` (the name of the interface element), and the `hubnet-message-source` of the message (the name of the client the message came from).

On an enter message we create a turtle with a `user-id` that matches the `hubnet-message-source` which is the name that each user enters upon entering the activity, it is guaranteed to be unique.

```
to create-new-student
  create-students 1
  [
    set user-id hubnet-message-source
    set label user-id
    set step-size 1
    send-info-to-clients
  ]
end
```

At this point we set any other client variables to default values and send them to the clients if appropriate. We declared a `students-own` variable for every interface element on the client that holds state, that is, anything that would be a global variable on the server, sliders, choosers, switches and input boxes. It is important to make sure that these variables stay synchronized with the values visible on the client.

When the clients logout they send an exit message to the server which gives you a chance to clean up any information you have been storing about the client, in this case we merely have to ask the appropriate turtle to die.

```
to remove-student
  ask students with [user-id = hubnet-message-source]
  [ die ]
end
```

All other messages are interface elements identified by the `hubnet-message-tag` which is the name that appears in the client interface. Every time an interface element changes a message is sent to the server. Unless you store the state of the values currently displayed in the client interface will not be accessible in other parts of the model. That's why we've declared a `students-own` variable for every interface element that has a state (sliders, switches, etc). When we receive the message from the client we set the turtle variable to the content of the message:

```
if hubnet-message-tag = "step-size"
[
  ask students with [user-id = hubnet-message-source]
    [ set step-size hubnet-message ]
]
```

Since buttons don't have any associated data there is generally no associated turtle variable, instead they indicate an action taken by the client, just as with a regular button there is often procedure associated with each button that you call whenever you receive a message indicating the button has been pressed. Though it is certainly not required, the procedure is often a turtle procedure, that is, something that the student turtle associated with the message source can execute:

```
if command = "move left"
[ set heading 270
  fd 1 ]
```

Sending messages to clients

As mentioned earlier you can also send values to any interface elements that display information: monitors, sliders, switches, choosers, and input boxes (note that plots and the view are special cases that have their own sections). There are two primitives that allow you to send information `hubnet-send` and `hubnet-broadcast`. Broadcast sends the information to all the clients and send sends to a specific or a selected group of the clients. As suggested earlier, nothing on the client updates automatically, if a value changes on the server it is your responsibility as the model author to update monitors on the client and if you change a variable on the server associated with another interface element not as a response to a change message from that widget then you must also update the value on the client. For example say you have a slider on the client called step-size and a monitor called Step Size (note that the names must be different) you might write updating code like this:

```
if hubnet-message-tag = "step-size"
[
  ask student with [ user-id = hubnet-message-source ]
  [
    set step-size hubnet-message
    hubnet-send user-id "Step Size" step-size
  ]
]
```

You can send any type of data you want, numbers, strings, lists, lists of lists, lists of strings, however, if the data is not appropriate for the receiving interface element (say, if you were to send a string to a slider) the message will be ignored. Here are a few code examples for different types of data:

data type	`hubnet-broadcast` example	`hubnet-send` example
number	`hubnet-broadcast "A" 3.14`	`hubnet-send "jimmy" "A" 3.14`
string	`hubnet-broadcast "STR1" "HI THERE"`	`hubnet-send ["12" "15"] "STR1" "HI THERE"`
list of numbers	`hubnet-broadcast "L2" [1 2 3]`	`hubnet-send hubnet-message-source "L2" [1 2 3]`
matrix of numbers	`hubnet-broadcast "[A]" [[1 2] [3 4]]`	`hubnet-send "susie" "[A]" [[1 2] [3 4]]`
list of strings (only for Computer HubNet)	`hubnet-broadcast "user-names" [["jimmy" "susie"] ["bob" "george"]]`	`hubnet-send "teacher" "user-names" [["jimmy" "susie"] ["bob" "george"]]`

Examples

Study the models in the "HubNet Computer Activities" and the "HubNet Calculator Activities" sections of the Models Library to see how these primitives are used in practice in the Procedures window. Disease is a good one to start with.

Calculator HubNet Information

For information on writing HubNet activities using calculator clients, please contact us.

Computer HubNet Information

The following information is specific to Computer HubNet.

How To Make a Client Interface

Open the HubNet Client Editor, found in the Tools Menu. Add any buttons, sliders, switches, monitors, plots, choosers, or notes that you want just as you would in the interface tab. You'll notice that the information you enter for each of the widgets is slightly different than in the Interface panel. Widgets on the client don't interact with the model in the same way. Instead of a direct link to commands and reporters the widgets send messages back to the server and the model then determines how those messages affect the model. All widgets on the client have a tag which is a name that uniquely identifies the widget. When the server receives a message from that widget the tag is found in `hubnet-message-tag`

For example, if you have a button called "move left", a slider called "step-size", a switch called "all-in-one-step?", and a monitor called "Location:", the tags for these interface elements will be as follows:

interface element	tag
move left	move left
step-size	step-size
all-in-one-step?	all-in-one-step?
Location:	Location:

Note that you can only have **one** interface element with a specific name. Having more than one interface element with the same tag in the client interface will result in unpredictable behavior since it is not clear which element you intended to send the information to.

View Updates on the Clients

The simplest way to display the world in the view on the client is to use view mirroring. When view mirroring is on (enabled through the HubNet Control Center) the client views are automatically updated to reflect the state of the world. All the clients will have the same view which is the same as the view on the server. The view updates are triggered about 5 times per second which means that there could be a lot of messages sent to the clients. If you are having trouble with performance you may want to try using no-display and display to reduce the number of updates sent to the clients.

If you would like to have more control over the view updates you can use `hubnet-broadcast-view` and `hubnet-send-view` to explicitly send the view either to all the clients or particular clients, respectively. However, you should note that view mirroring only updates the information that has changed since the last update whereas send and broadcast view send all of the world information every time. That means that the messages could be bigger (a lot bigger) and therefore slower to update.

If there is no View in the clients or if the Mirror 2D View on Clients checkbox in the HubNet Control Center is not checked, then no view messages are sent to the clients.

> **NOTE:** Since `hubnet-broadcast-view` and `hubnet-send-view` are experimental primitives, the behavior may change in a future release.

Note: Some of the View features in NetLogo are not yet implemented on the HubNet clients such as View Wrapping and Observer Perspectives.

Clicking in the View on Clients

If the View is included in the client, a message is sent to the server every time the user clicks in the view. The tag of the message is "View" and the message consists of a two item list of the x and y coordinates. For example, to turn any patch that was clicked on by the client red, you would use the following NetLogo code:

```
if hubnet-message-tag = "View"
[
  ask patches with [ pxcor = (round item 0 hubnet-message) and
                     pycor = (round item 1 hubnet-message) ]
  [ set pcolor red ]
]
```

Plot Updates on the Clients

If plot mirroring is enabled (in the HubNet Control Center) and a plot in the NetLogo model changes and a plot with the exact same name exists on the clients, a message with that change is sent to the clients causing the client's plot to make the same change. For example, let's pretend there is a HubNet model that has a plot called Milk Supply in NetLogo and the clients. Milk Supply is the current plot in NetLogo and in the Command Center you type:

```
plot 5
```

This will cause a message to be sent to all the clients telling them that they need to plot a point with a y value of 5 in the next position of the plot. Notice, if you are doing a lot of plotting all at once, this can generate a lot of plotting messages to be sent to the clients.

Logging

NetLogo's logging facility allows researchers to record students' actions for later analysis.

Logging in NetLogo, once initiated, is invisible to the user. The researcher can choose the type of events logged through a configuration file.

NetLogo uses the Log4j package for logging. If you have previous experience with this package you'll find logging in NetLogo familiar.

Starting logging

This depends on what operating system you are using.

Mac OS X or Windows

There is a special logging launcher in the NetLogo directory called NetLogo Logging. Double click on the icon.

On Windows, the NetLogo directory can be found at `C:\Program Files`, unless you chose a different location when you installed NetLogo.

Linux and others

from the command line start NetLogo like this:

```
java −server −Xms16M −Xmx1024M −cp NetLogo.jar \
  org.nlogo.app.App −−logging netlogo_logging.xml
```

You can replace netlogo_logging.xml with any valid log4j xml configuration file, which will be discussed in more detail later.

Using logging

When NetLogo starts up it will ask for a user name. This name will appear in all the logs generated during this session.

Where logs are stored

Logs are stored in the OS−specific temp directory. On most Unix−like systems (including MacOS) that is `/tmp`. On Windows XP, logs can be found in `c:\Documents and Settings\<user>\Local Settings\Temp`, where `<user>` is the logged in user and on Windows Vista the logs can be found in `c:\Users\<user>\AppData\Local\Temp`.

There are two convenience commands that will help you manage the logs. `__zip−log−files` *`filename`* will gather all the logs in the temp directory and put them in one zip file, at the location specified. After doing `__zip−log−files` the existing logs are **not** deleted, you can do so explicitly by using `__delete−log−files`.

The following is a chart describing the name of the loggers available, the type of events each logs, at what level, and provides a sample output using the XMLLayout. All the loggers are found in `org.nlogo.api.Logger`. When referring to the loggers in the configuration file you should use the fully qualified name. So, for example, the logger `GLOBALS` would actually be `org.nlogo.api.Logger.GLOBALS`

Logger	Events	Level	Example
`GLOBALS`	a global variable changes	info, debug	`<event logger="org.nlogo.api.Logger.GLOBALS" timestamp="1177341065988" level="INFO" type="globals"> <name>FOO</name> <value>51.0</value> </event>`
`GREENS`	sliders, switches, choosers, input boxes are changed through the interface	info	`<event logger="org.nlogo.api.Logger.GREENS" timestamp="1177341065988" level="INFO" type="slider"> <action>changed</action> <name>foo</name> <value>51.0</value> <parameters> <min>0.0</min> <max>100.0</max> <inc>1.0</inc> </parameters> </event>`
`CODE`	code is compiled, including: command center, procedures tab, slider bounds, and buttons	info	`<event logger="org.nlogo.api.Logger.CODE" timestamp="1177341072208" level="INFO" type="command center"> <action>compiled</action> <code>crt 1</code> <agentType>O</agentType> <errorMessage>success</errorMessage> </event>`
`WIDGETS`	a widget is added or removed from the interface	info	`<event logger="org.nlogo.api.Logger.WIDGETS" timestamp="1177341058351" level="INFO" type="slider"> <name></name> <action>added</action> </event>`
`BUTTONS`	a button is pressed or released	info	`<event logger="org.nlogo.api.Logger.BUTTONS" timestamp="1177341053679" level="INFO" type="button"> <name>show 1</name> <action>released</action> <releaseType>once</releaseType> </event>`
`SPEED_SLIDER`	the speed slider changes	info	`<event logger="org.nlogo.api.Logger.SPEED" timestamp="1177341042202" level="INFO" type="speed">`

			<value>0.0</value> </event>
TURTLES	turtles die or are born	info	<event logger="org.nlogo.api.Logger.TURTLES" timestamp="1177341094342" level="INFO" type="turtle"> <name>turtle 1</name> <action>born</action> <breed>TURTLES</breed> </event>
LINKS	links die or are born	info	<event logger="org.nlogo.api.Logger.LINKS" timestamp="1177341094347" level="INFO" type="link"> <name>link 0 1</name> <action>born</action> <breed>LINKS</breed> </event>

How to configure the logging output

The default logging configuration (netlogo_logging.xml) looks something like this:

NetLogo defines 8 loggers, all descend directly from the root logger, which means unless you explicitly set the properties (appender, layout, and output level) in the configuration they will inherit them from the root. In the default configuration the root is set to level INFO, the appender is org.nlogo.api.XMLFileAppender and layout is org.nlogo.api.XMLLayout. Together these generate a nicely formatted XML file as defined in the netlogo_logging.dtd which is based on the log4j dtd. If the appender is a FileAppender (including the XMLFileAppender) a new file is start each time the user opens a model.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!DOCTYPE log4j:configuration SYSTEM "log4j.dtd">

<log4j:configuration debug="false" xmlns:log4j='http://jakarta.apache.org/log4j/'>

        <appender name="A1" class="org.nlogo.api.XMLFileAppender">
           <layout class="org.nlogo.api.XMLLayout"/>
        </appender>

        <category name="org.nlogo.api.Logger.WIDGETS">
          <priority value="off" />
        </category>

        <category name="org.nlogo.api.Logger.TURTLES">
          <priority value="off" />
        </category>

        <category name="org.nlogo.api.Logger.LINKS">
          <priority value="off" />
        </category>

        <root>
           <priority value ="info" />
           <appender-ref ref="A1" />
        </root>
```

```
</log4j:configuration>
```

This configuration, first defines an appender named "A1" of type XMLFileAppender with an XMLLayout. The appender defines where the logging data goes, in this case the data goes into a file. In fact, if NetLogo is given a FileAppender it will automatically start a new file every time the user opens a new model. The XMLFileAppender also does some formatting and writes the appropriate headers to the file. The layout defines how to write each individual message. Unless you are an advanced user there is no need change (or worry about) the appender or the layout.

At the end of the configuration notice the definition of the root logger. All of the other loggers descend from the root logger and, thus, inherit the properties of the root unless explicitly set. This case is fairly simple, having set up the appender A1 we make that the default appender for the root (and all other loggers) and make the default priority "INFO". Messages that are logged at the INFO level or higher will be written, messages logged at lower levels will not. Note that with only one exception NetLogo always logs at level INFO. Sets to globals that don't change the value of the global are logged at level DEBUG. Which means that these messages are disabled by default, since debug is lower level than info. The rest of the body of the configuration file overrides properties of the root logger in a few specific loggers (or categories as they are known in the configuration file, the terms can be assumed to be synonymous for the proposes of this document). That is it turns off the WIDGET, TURTLES, and LINKS loggers, by default. To re−enable them you can changes the priority from off to info, like this:

```
<category name="org.nlogo.api.Logger.TURTLES">
  <priority value="info" />
</category>
```

or you can simply remove the entire reference to the category from the configuration file, as it is not serving any other purpose.

Advanced Configuration

This is only a basic introduction to configuration files for logging in NetLogo. There are many more configuration options available through the log4j framework. See the log4j documentation.

Controlling Guide

NetLogo can be invoked from another Java program and controlled by that program. For example, you might want to call NetLogo from a small program that does something simple like automate a series of model runs.

This section of the User Manual introduces this facility for Java programmers. We'll assume that you know the Java language and related tools and practices.

Note: The controlling facility is considered "experimental". It is likely to continue to change and grow. Code you write now that uses it may need changes in order to continue to work in future NetLogo versions.

- Note on memory usage
- Example (with GUI)
- Example (headless)
- BehaviorSpace
- Other Options
- Conclusion

The NetLogo API Specification contains further details.

Note on memory usage

In all of the examples below, when invoking Java to run them, you probably don't want to accept the default heap size settings. Most Java VM's have a very small initial heap size and a small maximum heap size too. When you run the NetLogo application, it uses an initial heap size of 16 megabytes and a maximum heap size of one gigabyte. This is enough for most models. Here's how to specify the heap sizes on the command line:

```
java −server −Dsun.java2d.noddraw=true −Xms16M −Xmx1024M ...
```

(Note that we recommend the `−server` flag for best performance in most situations. On Windows, we also recommend setting the noddraw option to true when using the GUI as Direct Draw can conflict with OpenGL.)

Example (with GUI)

Here is a small but complete program that starts the full NetLogo application, opens a model, moves a slider, sets the random seed, runs the model for 50 ticks, and then prints a result:

```
import org.nlogo.app.App;
import java.awt.EventQueue;

public class Example1 {
    public static void main(String[] argv) {
        App.main(argv);
        try {
            EventQueue.invokeAndWait
                ( new Runnable()
                    { public void run() {
```

```
                    try {
                      App.app.open
                          ("models/Sample Models/Earth Science/"
                           + "Fire.nlogo");
                    }
                    catch( java.io.IOException ex ) {
                      ex.printStackTrace();
                    }
                  } } );
            App.app.command("set density 62");
            App.app.command("random-seed 0");
            App.app.command("setup");
            App.app.command("repeat 50 [ go ]");
            System.out.println
                (App.app.report("burned-trees"));
        }
        catch(Exception ex) {
            ex.printStackTrace();
        }
    }
}
```

In order to compile and run this, `NetLogo.jar` (from the NetLogo distribution) must be in the classpath. In addition, the `lib` directory (also from the NetLogo distribution) must be in same location; it contains additional libraries used by `NetLogo.jar`.

Note the use of `EventQueue.invokeAndWait` to ensure that a method is called from the right thread. This is because most of the methods on the `App` class may only be called some certain threads. Most of the methods may *only* be called from the AWT event queue thread; but a few methods, such as `commmand()`, may only be called from threads *other* than the AWT event queue thread (such as, in this example, the main thread).

Rather than continuing to discuss this example in full detail, we refer you to the NetLogo API Specification, which documents all of the ins and outs of the classes and methods used above. Additional methods are available as well.

Example (headless)

The example code in this case is very similar to the previous example, but with methods on an instance of the `HeadlessWorkspace` class substituted for static methods on `App`.

```
import org.nlogo.headless.HeadlessWorkspace;

public class Example2 {
    public static void main(String[] argv) {
        HeadlessWorkspace workspace =
            new HeadlessWorkspace() ;
        try {
            workspace.open
                ("models/Sample Models/Earth Science/"
                 + "Fire.nlogo");
            workspace.command("set density 62");
            workspace.command("random-seed 0");
            workspace.command("setup");
            workspace.command("repeat 50 [ go ]") ;
            System.out.println
                (workspace.report("burned-trees"));
```

```
            workspace.dispose();
        }
        catch(Exception ex) {
            ex.printStackTrace();
        }
    }
}
```

In order to compile and run this, either `NetLogo.jar` or `NetLogoLite.jar` (from the NetLogo distribution) must be in your classpath. (The latter jar is smaller, but is only capable of headless operation, not full GUI operation.) The `lib` directory, containing additional required libraries, must also be present. When running in a context that does not support a graphical display, the system property `java.awt.headless` must be true, to force Java to run in headless mode; HeadlessWorkspace automatically sets this property for you.

Since there is no GUI, NetLogo primitives which send output to the command center or output area now go to standard output instead. `export-world` can still be used to save the model's state. `export-view` works for writing an image file with a snapshot of the (otherwise invisible) 2D view. The `report()` method is useful for getting results out of the model and into your Java code.

The files generated by `export-world` include the contents of all plots. You can also export the contents of plots individually using `export-plot`.

You can make multiple instances of `HeadlessWorkspace` and they will operate independently on separate threads without interfering with each other.

When running headless, there are some restrictions:

- The `movie-*` primitives are not available; trying to use them will cause a Java exception.
- `user-*` primitives which query the user for input, such as `user-yes-or-no` will cause a Java exception.

The NetLogo API Specification contains further details.

BehaviorSpace

The Controlling API supports running BehaviorSpace experiments headless. (It does not support running them in BehaviorSpace's GUI, although you can write your own BehaviorSpace-like Java code to run your own BehaviorSpace-like experiments if you want.)

Note that it is definitely not necessary to use the API to do headless BehaviorSpace runs. Headless BehaviorSpace is supported directly from the command line with no Java programming at all required. See the BehaviorSpace Guide for instructions.

In most cases, the command line support will be enough, without needing to use the API. In some situations, though, you may want additional flexibility afforded by the API.

The `HeadlessWorkspace` has four methods for running experiments: three variants of `runExperiment`, plus `runExperimentFromModel`.

`runExperimentFromModel` is used when the experiment setup is already stored in the model file.

The two forms of `runExperiment` that take `File` arguments are used when the experiment setup is stored in a standalone XML file, separate from the model file. If the file contains only one setup, you only need to pass in the `File` object. If the file contains multiple setups, you must also pass in a `String` object holding the experiment name.

The form of `runExperiment` that takes only a `String` argument (and an argument to specify the output format) is used to pass the XML for the experiment setup directly.

All of these methods take a PrintWriter as a destination for the results. If you just want to send them to standard output, you can pass `new java.io.PrintWriter( System.out )`.

The BehaviorSpace Guide explains how to specify experiment setups in XML.

The NetLogo API Specification contains further details on the `HeadlessWorkspace` class and its methods.

Other Options

When your program controls NetLogo using the App class, the entire NetLogo application is present, including tabs, menubar, and so forth. This arrangement is suitable for controlling or "scripting" a NetLogo model, but not ideal for embedding a NetLogo model in a larger application.

We also have a separate, similar API which allows embedding only parts of NetLogo, such as only the tabs (not the whole window), or only the contents of the Interface tab. At present, this additional API is not documented. If you are interested in using it, please contact us at feedback@ccl.northwestern.edu.

Conclusion

Don't forget to consult the NetLogo API Specification for full details on these classes and methods.

As mentioned before, the controlling facility is considered experimental. This initial API doesn't necessarily include everything you might expect. Some facilities exist, but are not yet documented. So if you don't see the capability you want, contact us; we may be able to help you do you what you want. Please do not hesitate to contact us at feedback@ccl.northwestern.edu with questions, as we may be able to find a workaround or provide additional guidance where our documentation is thin.

Mathematica Link

What is it?

The NetLogo−Mathematica link provides modelers with an easy to use, real−time link between NetLogo and Mathematica. Together, these tools can provide users with a highly interactive, self−documenting work flow that neither can provide alone.

Mathematica includes many of the tools that agent−based modelers rely on throughout the research process: advanced import capabilities, statistical functions, data visualization, and document creation. With the NetLogo−Mathematica link, you can run all of these tools side−by−side with NetLogo.

Because all Mathematica documents, or notebooks, contain comments, code, images, annotations, and interactive objects, the integration of NetLogo and Mathematica provides a more complete solution for complex model exploration for students and researchers alike.

The basic functionality of the link is much like the NetLogo Controlling API: you can load models, execute commands, and report back data from NetLogo. Unlike the Controlling API, which is based on Java, all interactions with the link are interpreted, making it ideal not only for rapidly designing custom BehaviorSpace−like experiments, but also as a companion to NetLogo in debugging your model.

For more information about Mathematica, please visit the Wolfram Research web site.

What can I do with it?

Here are a few examples of what you can do with the Mathematica−NetLogo link.

- Analyze your model in real−time with seamless two−way data conversion
- Develop high quality, custom visualizations of model data
- Collect detailed simulation data across large multi−dimensional parameter spaces
- Rapidly develop interactive interfaces for exploring model behavior
- Have direct access to patches and network data with built−in functions

Using the NetLogo−Mathematica Link

This section will very briefly introduce how to use the NetLogo−Mathematica Link. It will show you how to load the NetLogo−Mathematica link package, start NetLogo, execute commands, and retrieve data from NetLogo.

Loading the package: Once the NetLogo−Mathematica link is installed, you can load the package by entering the following into your Mathematica notebook:

```
<<NetLogo`
```

Launching NetLogo from Mathematica: To begin your NetLogo session in Mathematica, type the following into your notebook:

```
NLStart["your netlogo path"];
```

where *"your netlogo path"* is the directory that netlogo is located in. Typically on a Macintosh computer this will be "/Applications/NetLogo 4.0/"

Loading a model: To load a model, you must specify the full path of the model. In this example we will load the Forest Fire model, and the path will be given using the typical Macintosh install location.

```
NLLoadModel["/Applications/NetLogo 4.0/models/Sample
Models/Earth Science/Fire.nlogo"];
```

Executing a NetLogo command: Commands can be executed by passing a string of commands to `NLCommand[]`. The `NLCommand[]` function automatically splices common Mathematica data types into strings suitable for NetLogo. The following commands set the density using a single string, or set the density using a Mathematica defined variable, `myDensity`.

```
NLCommand["set density 50"];
myDensity = 60;
NLCommand["set density", myDensity];
```

Reporting information from NetLogo: NetLogo data can be reported back to Mathematica using `NLReport[]`. This includes numbers, strings, boolean values, and lists.

```
NLReport["count turtles"];
NLReport["[(list pxcor pycor)] of n-of 10 patches"]
```

For more information, see the NetLogo−Mathematica Tutorial notebook included with NetLogo. The notebook walks you through the process of using the link, with many examples along the way. If you do not have Mathematica, but are considering using the link, you can download a PDF of the evaluated tutorial.

Installation

The NetLogo−Mathematica link requires NetLogo 4.0 and Mathematica 6.0 or greater. To install the NetLogo−Mathematica link:

- Go to the menu bar in Mathematica
- Click on File and select Install...
- In the Install Mathematica Item dialog

- Select Package for Type of item to install
- Click Source, and select From file...
- In the file browser, go to the location of your NetLogo installation,
- click on the Mathematica Link subfolder, and select NetLogo.m.
- For Install Name, enter NetLogo.

You can either install the NetLogo link in your user base directory or in the system−wide directory. If the NetLogo link is installed in the user base directory, other users on the system must also go through the NetLogo−Mathematica link installation process to use it. This option might be preferable if you do not have permission to modify files outside of your home directory. Otherwise, you can install NetLogo−Mathematica link in the system−wide Mathematica base directory.

Known Issues

- A NetLogo session cannot be quit without exiting J/Link (the Java−Mathematica link) entirely. This may disrupt other packages that make use of J/Link. This problem will be resolved in a future version.
- If a model loaded with the NetLogo−Mathematica link uses a NetLogo extension, the extension must be located in the same directory as the extension itself. If the extension is located in NetLogo's application−wide extensions directory, it will not be found. This problem will be resolved in a future version.
- Calls to NetLogo, such as `NLCommand[]` and `NLReport[]`, cannot be aborted.

Credits

The primary developer of the NetLogo−Mathematica link was Eytan Bakshy.

To refer to this package in academic publications, please use: Bakshy, E., Wilensky, U. (2007). NetLogo−Mathematica Link. http://ccl.northwestern.edu/netlogo/mathematica.html. Center for Connected Learning and Computer−Based Modeling, Northwestern University, Evanston, IL.

Extensions Guide

NetLogo allows users to write new commands and reporters in Java and use them in their models. This section of the User Manual introduces this facility.

The first part discusses how to use an extension in your model once you have written one, or once someone has given you one.

The second part is intended for Java programmers interested in writing their own extensions using the NetLogo Extension API.

- Using Extensions
- Writing Extensions

The NetLogo Extension API Specification contains further details.

Using Extensions

To use an extension in a model, add the `extensions` keyword at the beginning of the Procedures tab, before declaring any breeds or variables.

After `extensions` comes a list of extension names in square brackets. For example:

```
extensions [sound speech]
```

Using `extensions` tells NetLogo to find and open the specified extension and makes the custom commands and reporters found in the extension available to the current model. You can use these commands and reporters just as if they were built−in NetLogo primitives.

Where extensions are located

NetLogo will look for extensions in several places:

1. In the folder of the current model.
2. The `extensions` folder in the same location as the NetLogo application.

Each NetLogo extension consists of a folder with the same name as the extension, entirely in lower case. This folder must contain a JAR file with the same name as the folder. For example the `sound` extension is stored in a folder called `sound` with a file inside called `sound.jar`. For more information about the contents of an extension's folder, please see the section of this manual on Writing Extensions.

To install a NetLogo extension for use by any model, put the extension's folder in the `extensions` directory in the NetLogo directory. Or, you can just keep the extension's folder in the same folder as the model that uses it.

Some extensions depend on additional files. These files will be in the extension's folder along with the JAR file. The folder may also contain other files such as documentation and example models.

Applets

Models saved as applets (using "Save as Applet" on NetLogo's File menu) can make use of extensions. The extension must be placed in the same directory holding the model file. However, applets still cannot use extensions that require additional external jars. (We plan on fixing this in a later release.)

Writing Extensions

We assume you have experience programming in Java.

Summary

A NetLogo extension consists of a folder with the following contents: **Required:**

- A JAR file with the same name as the extension, the following contents:
  - one or more classes that implementation `org.nlogo.api.Primitive`,
  - a main class that implements `org.nlogo.api.ClassManager`, and
  - a NetLogo extension manifest file, with the following four tags:
    - `Manifest-Version`, always 1.0
    - `Extension-Name`, the name of the extension.
    - `Class-Manager`, the fully-qualified name of a class implementing `org.nlogo.api.ClassManager`.
    - `NetLogo-Extension-API-Version`, the version of NetLogo Extension API for which this JAR is intended. If a user opens the extension with NetLogo that has a different Extension API version, a warning message is issued. To tell which version of the Extension API your NetLogo supports, choose the "About NetLogo" item in the "Help" menu and then click on the System tab. Or, you can launch `NetLogo.jar` with the `--extension-api-version` argument.

Optional:

- One or more NetLogo models demonstrating how the extension is used.
- One or more JAR files which the extension requires.
- A `lib` directory with any required native libraries.
- A `src` directory containing the source code for the model
- Documentation.

To build your extension, you must include NetLogo.jar in your class path.

Examples

Several sample extensions with full Java source code are included with NetLogo. Some others are available for download here.

Tutorial

Let's write an extension that provides a single reporter called `first-n-integers`.

`first-n-integers` will take a single numeric input *n* and report a list of the integers 0 through n − 1. (Of course, you could easily do this just in NetLogo; it's only an example.)

1. Create extension folder

Since an extension is a folder with several items, we first need to create our folder. In this example, it is called `example`. We will be doing all of our work in that folder. We will also want to create a `src` sub-folder to hold our Java code, and a `classes` sub-folder for the compiled classes.

2. Write primitives

The primitives are implemented as one or more Java classes. The .java files for these classes should be put in the `src` sub-folder.

A command performs an action; a reporter reports a value. To create a new command or reporter, create a class that implements the interface `org.nlogo.api.Command` or `org.nlogo.api.Reporter`, which extend `org.nlogo.api.Primitive`. In most cases, you can extend the abstract class `org.nlogo.api.DefaultReporter` or `org.nlogo.api.DefaultCommand`.

`DefaultReporter` requires that we implement:

```
Object report (Argument args[], Context context)
  throws ExtensionException;
```

Since our reporter takes an argument, we also implement:

```
Syntax getSyntax();
```

Here's the implementation of our reporter, in a file called `src/IntegerList.java`:

```
import org.nlogo.api.*;

public class IntegerList extends DefaultReporter
{
    // take one number as input, report a list
    public Syntax getSyntax() {
        return Syntax.reporterSyntax(
            new int[] {Syntax.TYPE_NUMBER}, Syntax.TYPE_LIST
        );
    }

    public Object report(Argument args[], Context context)
        throws ExtensionException
    {
        // create a NetLogo list for the result
        LogoList list = new LogoList();

        int n ;
        // use typesafe helper method from
        // org.nlogo.api.Argument to access argument
```

```
        try
        {
            n = args[0].getIntValue();
        }
        catch( LogoException e )
        {
            throw new ExtensionException( e.getMessage() ) ;
        }

        if (n < 0) {
            // signals a NetLogo runtime error to the modeler
            throw new ExtensionException
              ("input must be positive");
        }

        // populate the list
        // note that we use Double objects; NetLogo numbers
        // are always doubles
        for (int i = 0; i < n; i++) {
            list.add(new Double(i));
        }
        return list;
    }
}
```

Notice:

- Note that the number objects we put in the list are Doubles, not Integers. All numbers used as NetLogo values must be of type Double, even if they happen to have no fractional part.
- To access arguments, use `org.nlogo.api.Argument`'s typesafe helper methods, such as `getDoubleValue()`.
- Throw `org.nlogo.api.ExtensionException` to signal a NetLogo runtime error to the modeler.

A `Command` is just like a `Reporter`, except that reporters implement `Object report(...)` while commands implement `void perform(...)`.

2. Write a ClassManager

Each extension must include, in addition to any number of command and reporter classes, a class that implements the interface `org.nlogo.api.ClassManager`. The ClassManager tells NetLogo which primitives are part of this extension. In simple cases, extend the abstract class `org.nlogo.api.DefaultClassManager`, which provides empty implementations of the methods from `ClassManager` that you aren't likely to need.

Here's the class manager for our example extension, `src/SampleExtension.java`:

```
import org.nlogo.api.*;

public class SampleExtension extends DefaultClassManager {
    public void load(PrimitiveManager primitiveManager) {
        primitiveManager.addPrimitive
          ("first-n-integers", new IntegerList());
    }
}
```

`addPrimitive()` tells NetLogo that our reporter exists and what its name is.

3. Write a Manifest

The extension must also include a manifest. The manifest is a text file which tells NetLogo the name of the extension and the location of the `ClassManager`.

The manifest must contain three tags:

- `Extension-Name`, the name of the extension.
- `Class-Manager`, the fully-qualified name of a class implementing `org.nlogo.api.ClassManager`.
- `NetLogo-Extension-API-Version`, the version of NetLogo Extension API for which this JAR is intended. If a user opens the extension with NetLogo that has a different Extension API version, a warning message is issued. To tell which version of the Extension API your NetLogo supports, choose the "About NetLogo" item in the "Help" menu. Or, you can launch the `NetLogo.jar` with the `--extension-api-version` argument.

Here's a manifest for our example extension, `manifest.txt`:

```
Manifest-Version: 1.0
Extension-Name: example
Class-Manager: SampleExtension
NetLogo-Extension-API-Version: 4.0
```

The NetLogo-Extension-API-Version line should match the actual version of NetLogo Extension API you are using.

Make sure even the last line ends with a newline character.

4. Create a JAR

To create an extension's JAR file, first compile your classes as usual, either from the command line or using an IDE.

Important: You must add `NetLogo.jar` (from the NetLogo distribution) to your classpath when compiling.

Here's an example of how compiling your extension might look from the command line:

```
$ mkdir -p classes     # create the classes subfolder if it does not exist
$ javac -classpath NetLogo.jar -d classes src/IntegerList.java src/SampleExtension.java
```

You will need to change the classpath argument to point to the NetLogo.jar file from your NetLogo installation. This command line will compile the .java and put the .class files in the `classes` subfolder.

Then create a JAR containing the resulting class files and the manifest. For example:

```
$ jar cvfm example.jar manifest.txt -C classes .
```

For information about manifest files, JAR files and Java tools, see java.sun.com.

5. Use your extension in a model

To use our example extension, put the `example` folder in the NetLogo extensions folder, or in the same directory as the model that will use the extension. At the top of the Procedures tab write:

```
extensions [example]
```

Now you can use `example:first-n-integers` just like it was a built-in NetLogo reporter. For example, select the Interface tab and type in the Command Center:

```
observer> show example:first-n-integers 5
observer: [0 1 2 3 4]
```

Extension development tips

Instantiation

Your class manager is instantiated at the time a model using the extension is loaded.

Command and reporter objects are instantiated whenever NetLogo code is compiled that uses your commands and reporters.

Classpath

Don't forget to include NetLogo.jar in your class path when compiling. This is the most common mistake made by new extension authors. (If the compiler can't find NetLogo.jar, you'll get error messages about classes in the org.nlogo.api package not being found.)

Debugging extensions

There are special NetLogo primitives to help you as you develop and debug your extension. These are considered experimental and may be changed at a later date. (That's why they have underscores in their name.)

- `print __dump-extensions` prints information about loaded extensions
- `print __dump-extension-prims` prints information about loaded extension primitives
- `__reload-extensions` forces NetLogo to reload all extensions the next time you compile your model. Without this command, changes in your extension JAR will not take effect until you open a model or restart NetLogo.

Third party JARs

If your extension depends on code stored in a separate JAR, copy the extra JARs into the extension. Whenever an extension is imported, NetLogo makes all the JARs in its folder available to the extension.

If you plan to distribute your extension to other NetLogo users, make sure to provide installation instructions.

Supporting old Java versions

NetLogo works with Java versions 1.4.1 and later. If you want your extension to be usable by all NetLogo users, your extension should support Java 1.4.1.

The easiest way is to accomplish this is do all your development with the 1.4.1 JDK.

It's also possible to develop for Java 1.4 using the Java 1.5 or 1.6 compiler, but you need to do two things:

- Use the `-target 1.4` option to javac (or equivalent in your IDE) to tell the newer compiler to emit class files that are compatible with the older Java versions. This ensures that your code doesn't use any 1.5−only or 1.6−only Java language features.
- Use the `-bootclasspath` option to javac (or IDE equivalent) to compile against the 1.4 Java class libraries. (Note that this requires installing the JDK 1.4 anyway.) This ensures that your code doesn't make any 1.5−only or 1.6−only Java API calls.

Conclusion

Don't forget to consult the NetLogo API Specification for full details on these classes, interfaces, and methods.

Note that there is no way for the modeler to get a list of commands and reporters provided by an extension, so it's important that you provide adequate documentation.

The extensions facility is not yet complete. The API doesn't include everything you might expect to be present. Some facilities exist but are not yet documented. If you don't see a capability you want, please let us know. Do not hesitate to contact us at feedback@ccl.northwestern.edu with questions, as we may be able to find a workaround or provide additional guidance where our documentation is thin.

Hearing from users of this API will also allow us to appropriately focus our efforts for future releases. We are committed to making NetLogo flexible and extensible, and we very much welcome your feedback.

Array and Table Extensions

These extensions add two new data structures to NetLogo, arrays and hash tables.

When to use

In general, anything you can do with an array or table, you could also just use a list for. But you may want to consider using an array or table instead for speed reasons. All three data structures (list, array, and table) have different performance characteristics, so you may be able to make your model run faster by selecting the appropriate data structure.

Arrays are useful when you need a collection of values whose size is fixed. You can quickly access or alter any item in an array if you know its position.

Tables are useful when you need to do associate values with other values. For example, you might make a table of words and their definitions. Then you can look up the definition of any word. Here, the words are the "keys". You can easily retrieve the value for any key in the table, but not vice versa.

How to use

Both extensions come preinstalled.

To use the array extension in your model, add a line to the top of your procedures tab:

```
extensions [array]
```

To use the table extension in your model, add a line to the top of your procedures tab:

```
extensions [table]
```

You can use both extensions in the same model if you want, as follows:

```
extensions [array table]
```

If your model already uses other extensions, then it already has an `extensions` line in it, so just add `array` and/or `table` to the list.

For more information on using NetLogo extensions, see the Extensions Guide.

Limitation on table keys

Table keys may only be strings, numbers, booleans, or lists. (Lists may be arbitrarily nested lists as long as all the items inside are strings, numbers, or booleans.)

Array example

```
let a array:from-list n-values 5 [0]
print a
```

```
=> {{array: 0 0 0 0 0}}
print array:length a
=> 5
foreach n-values 5 [?] [ array:set a ? ? * ? ]
print a
=> {{array: 0 1 4 9 16}}
print array:item a 0
=> 0
print array:item a 3
=> 9
array:set a 3 50
print a
=> {{array: 0 1 4 50 16}}
```

Table example

```
let dict table:make
table:put dict "turtle" "cute"
table:put dict "bunny" "cutest"
print dict
=> {{table: "turtle" -> "cute", "bunny" -> "cutest" }}
print table:length dict
=> 2
print table:get dict "turtle"
=> "cute"
print table:get dict "leopard"
=> 0
print table:keys dict
=> ["turtle" "bunny"]
```

Known issues

When you export a NetLogo world (using the `export-world` command or Export World menu item), arrays and tables are exported "by value". This means that if you have the same array or table stored in more than one location, then when it is exported and re-imported, there will now be distinct arrays or tables in the places the places the original array or table appeared. These duplicates will initially contain the same values, but if one duplicate is altered, the others will not change.

Array primitives

array:from-list array:item array:set array:length array:to-list

array:from-list

array:from-list *list*

Reports a new array containing the same items in the same order as the input list.

array:item

array:item *array index*

Reports the item in the given array with the given index (ranging from zero to the length of the array minus one).

array:set

array:set *array index value*

Sets the item in the given array with the given index (ranging from zero to the length of the array minus one) to the given value.

Note that unlike the `replace-item` primitive for lists, a new array is not created. The given array is actually modified.

array:length

array:length *array*

Reports the length of the given array, that is, the number of items in the array.

array:to-list

array:to-list *array*

Reports a new list containing the same items in the same order as the given array.

Table Primitives

table:clear table:from-list table:get table:has-key? table:keys table:length table:make table:put table:remove table:to-list

table:clear

table:clear *table*

Removes all key-value pairs from *table*.

table:from-list

table:from-list *list*

Reports a new table with the contents of *list*. *list* must be a list of two element lists, or pairs. The first element in the pair is the key and the second element is the value.

table:get

table:get *table key*

Reports the value that *key* is mapped to in the table. Causes an error if there is no entry for the key.

table:has−key?

table:has−key? *table key*

Reports true if *key* has an entry in *table*.

table:keys

table:keys *table*

Reports a list of all the keys in *table*.

table:length

table:length *table*

Reports the number of entries in *table*.

table:make

table:make

Reports a new, empty table.

table:put

table:put *table key value*

Maps *key* to *value* in *table*. If an entry already exists in the table for the given key, it is replaced.

table:remove

table:remove *table key*

Removes the mapping in *table* for *key*.

table:to−list

table:to−list *table*

Reports a list with the content of *table*. The list will be a list of two element lists, or pairs. The first element in the pair is the key and the second element is the value.

Sound Extension

The Sound Extension for NetLogo provides primitives to add sound to NetLogo models. It supports two ways of making sound: MIDI sounds, and playback of pre−recorded sound files.

Using the Sound Extension

The sound extension comes preinstalled. To use the extension in your model, add a line to the top of your procedures tab:

```
extensions [sound]
```

If your model already uses other extensions, then it already has an `extensions` line in it, so just add `sound` to the list.

For more information on using NetLogo extensions, see the Extensions Guide.

For examples that use the sound extension, see the Sound section under Code Examples in the NetLogo Models Library.

Note that the sound extension only works in the NetLogo application. It doesn't work in saved applets.

MIDI support

The MIDI part simulates a 128−key electronic keyboard with 47 drums and 128 melodic instruments, as provided by General MIDI Level 1 specification.

It supports 15 polyphonic instrument channels and a single percussion channel. Using more than 15 different melodic instruments simultaneously in a model will cause some sounds to be lost or cut off.

The pitch of a melodic instrument is specified by a key number. The keys on the keyboard are numbered consecutively from 0 to 127, where 0 is the left−most key. Middle C is key number 60.

The loudness of an instrument is specified by a velocity, which represents the force with which the keyboard key is depressed. Velocity ranges from 0 to 127, where 64 is the standard velocity. A higher velocity results in a louder sound.

Primitives

sound:drums sound:instruments sound:play−drum sound:play−note sound:play−note−later sound:play−sound sound:play−sound−and−wait sound:play−sound−later sound:start−note sound:stop−note sound:stop−instrument sound:stop−music

sound:drums

sound:drums

Reports a list of the names of the 47 drums for use with "sound:play−drum".

sound:instruments

sound:instruments

Reports a list of the names of the 128 instruments for use with "sound:play−note", "sound:play−note−later", "sound:start−note" and "sound:stop−note".

sound:play−drum

sound:play−drum *drum velocity*

Plays a drum.

```
sound:play−drum "ACOUSTIC SNARE" 64
```

sound:play−note

sound:play−note *instrument keynumber velocity duration*

Plays a note for a specified duration, in seconds. The agent does not wait for the note to finish before continuing to next command.

```
;; play a trumpet at middle C for two seconds
sound:play−note "TRUMPET" 60 64 2
```

sound:play−note−later

sound:play−note−later *delay instrument keynumber velocity duration*

Waits for the specified delay before playing the note for a specified duration, in seconds. The agent does not wait for the note to finish before continuing to next command.

```
    ;; in one second, play a trumpet at middle C for two seconds
sound:play−note−later 1 "TRUMPET" 60 64 2
```

sound:play−sound

sound:play−sound *filename*

Plays a sound file. It does not wait for the sound file to finish before moving to the next command. It supports WAV, AIFF, and AU files.

```
;; plays the beep.wav sample file
sound:play−sound "beep.wav"
```

sound:play−sound−and−wait

sound:play−sound−and−wait *filename*

Plays a sound file, waiting for it to finish playing before moving to the next command. It supports WAV, AIFF, and AU files.

```
;; plays the beep.wav sample file, waiting for it to finish before
;; playing boop.wav
sound:play−sound−and−wait "beep.wav"
sound:play−sound−and−wait "boop.wav"
```

sound:play−sound−later

sound:play−sound−later *filename delay*

Plays a sound file after the specified delay, in seconds. It does not wait for the sound file to play or finish before moving to the next command. It supports WAV, AIFF, and AU files.

```
;; plays the beep.wav sample file one second from now
sound:play−sound−later "beep.wav" 1
```

sound:start−note

sound:start−note *instrument keynumber velocity*

Starts a note.

The note will continue until "sound:stop−note", "sound:stop−instrument" or "sound:stop−music" is called.

```
;; play a violin at middle C
sound:start−note "VIOLIN" 60 64

;; play a C−major scale on a xylophone
foreach [60 62 64 65 67 69 71 72] [
  sound:start−note "XYLOPHONE" ? 65
  wait 0.2
  sound:stop−note "XYLOPHONE" ?
]
```

sound:stop−note

sound:stop−note *instrument keynumber*

Stops a note.

```
;; stop a violin note at middle C
sound:stop−note "VIOLIN" 60
```

sound:stop−instrument

sound:stop−instrument *instrument*

Stops all notes of an instrument.

```
;; stop all cello notes
sound:stop−instrument "CELLO"
```

sound:stop−music

sound:stop−music

Stops all notes.

Sound names

Drums

35. Acoustic Bass Drum
36. Bass Drum 1
37. Side Stick
38. Acoustic Snare
39. Hand Clap
40. Electric Snare
41. Low Floor Tom
42. Closed Hi Hat
43. Hi Floor Tom
44. Pedal Hi Hat
45. Low Tom
47. Open Hi Hat
47. Low Mid Tom
48. Hi Mid Tom
49. Crash Cymbal 1
50. Hi Tom
51. Ride Cymbal 1
52. Chinese Cymbal
53. Ride Bell
54. Tambourine
55. Splash Cymbal
56. Cowbell
57. Crash Cymbal 2
58. Vibraslap
59. Ride Cymbal 2
60. Hi Bongo
61. Low Bongo
62. Mute Hi Conga
63. Open Hi Conga
64. Low Conga
65. Hi Timbale
66. Low Timbale
67. Hi Agogo
68. Low Agogo
69. Cabasa
70. Maracas
71. Short Whistle
72. Long Whistle
73. Short Guiro
74. Long Guiro
75. Claves
76. Hi Wood Block
77. Low Wood Block
78. Mute Cuica
79. Open Cuica
80. Mute Triangle
81. Open Triangle

Instruments

Piano
1. Acoustic Grand Piano
2. Bright Acoustic Piano
3. Electric Grand Piano
4. Honky−tonk Piano
5. Electric Piano 1
6. Electric Piano 2
7. Harpsichord
8. Clavi

Reed
65. Soprano Sax
66. Alto Sax
67. Tenor Sax
68. Baritone Sax
69. Oboe
70. English Horn
71. Bassoon
72. Clarinet

Chromatic Percussion
9. Celesta
10. Glockenspiel
11. Music Box
12. Vibraphone
13. Marimba
14. Xylophone
15. Tubular Bells
16. Dulcimer

Organ
17. Drawbar Organ
18. Percussive Organ
19. Rock Organ
20. Church Organ
21. Reed Organ
22. Accordion
23. Harmonica
24. Tango Accordion

Guitar
25. Nylon String Guitar
26. Steel Acoustic Guitar
27. Jazz Electric Guitar
28. Clean Electric Guitar
29. Muted Electric Guitar
30. Overdriven Guitar
31. Distortion Guitar
32. Guitar harmonics

Bass
33. Acoustic Bass
34. Fingered Electric Bass
35. Picked Electric Bass
36. Fretless Bass
37. Slap Bass 1
38. Slap Bass 2
39. Synth Bass 1
40. Synth Bass 2

Strings
41. Violin
42. Viola
43. Cello
44. Contrabass
45. Tremolo Strings
47. Pizzicato Strings
47. Orchestral Harp
48. Timpani

Ensemble
49. String Ensemble 1
50. String Ensemble 2
51. Synth Strings 1
52. Synth Strings 2
53. Choir Aahs
54. Voice Oohs
55. Synth Voice
56. Orchestra Hit

Brass
57. Trumpet

Pipe
73. Piccolo
74. Flute
75. Recorder
76. Pan Flute
77. Blown Bottle
78. Shakuhachi
79. Whistle
80. Ocarina

Synth Lead
81. Square Wave
82. Sawtooth Wave
83. Calliope
84. Chiff
85. Charang
86. Voice
87. Fifths
88. Bass and Lead

Synth Pad
89. New Age
90. Warm
91. Polysynth
92. Choir
93. Bowed
94. Metal
95. Halo
96. Sweep

Synth Effects
97. Rain
98. Soundtrack
99. Crystal
100. Atmosphere
101. Brightness
102. Goblins
103. Echoes
104. Sci-fi

Ethnic
105. Sitar
106. Banjo
107. Shamisen
108. Koto
109. Kalimba
110. Bag pipe
111. Fiddle
112. Shanai

Percussive
113. Tinkle Bell
114. Agogo
115. Steel Drums
116. Woodblock
117. Taiko Drum
118. Melodic Tom
119. Synth Drum
120. Reverse Cymbal

Sound Effects
121. Guitar Fret Noise

58. Trombone
59. Tuba
60. Muted Trumpet
61. French Horn
62. Brass Section
63. Synth Brass 1
64. Synth Brass 2
122. Breath Noise
123. Seashore
124. Bird Tweet
125. Telephone Ring
126. Helicopter
127. Applause
128. Gunshot

GoGo Extension

What is the GoGo Board?

The GoGo Board extension lets you connect NetLogo to the physical world, using sensors, motors, light bulbs, LEDs, relays and other devices. The GoGo Extension for NetLogo provides primitives to communicate with a GoGo board via a serial interface.

A GoGo Board is an open source, easy−to−build, low cost, general purpose board especially designed to be used in educational projects. It was created by Arnan Sipitakiat at the MIT Media Lab. A GoGo Board has 8 sensor ports and 4 output ports, and also a connector for add−on boards (such as a display or a wireless communication module). Using the GoGo Board extension, NetLogo models can interact with the physical world in two ways. First, it can gather data from the environment, such as temperature, ambient light, or user input. This information can be used by the model to change or calibrate its behavior. Secondly, it can control output devices − NetLogo could control motors, toys, remote controlled cars, electrical appliances, light bulbs, and automated laboratory equipment.

How to get a GoGo Board?

The GoGo Board is not a commercial product, and thus cannot be bought at stores. To get a GoGo Board, you have to build one yourself or ask someone to do it for you. The board was especially designed to be easy and cheap to build, even if you don't have electronics skills. The main resource about the GoGo Board is the web site www.gogoboard.org, where you will find step−by−step instructions on how to buy components, design the printed circuit board, and assemble it. The GoGo Board mailing list is gogoboard@yahoogroups.com.

Installing the GoGo Extension

The GoGo Board needs to communicate with the computer in some way, and to do so it uses the serial port. The choice of this port instead of a USB port was motivated by the board's low cost principle: the components needed to build a USB compatible board would be more expensive. If your computer does not have a serial port, you need to purchase a USB−to−Serial adapter, which can be easily found in computer stores with prices ranging from US$ 15 to US$ 30 (if you have a Mac or Linux machine, make sure the adapter is compatible with your platform).

Mac OS X

In order to access the serial ports, the user you are logged in as needs to have permission to write to `/var/spool/uucp`. You can run the script `gogo/lib/Mac OS X/fix−permissions.command` to set up the permission appropriately. It will make that directory writable by the group `uucp` and then add your current login to that group. Double−click that file to run it.

Linux

You will need to be able to write the the serial devices, normally `/dev/ttyS*`. In most Linux distributions this can be set up thru the User Manager. Using the GoGo Extension

The GoGo Extensions comes preinstalled. To use the extension in your model, add a line to the top of your procedures tab:

```
extension [gogo]
```

If your model already uses other extensions, then it already has an `extensions` line in it, so just add `gogo` to the list.

After loading the extension, see what ports are available by typing the following into the command center:

```
print gogo:ports
```

You can open the serial port the GoGo Board is connected to with the `gogo:open` command, and see if the board is responding with the `ping` reporter.

On Windows:

```
gogo:open "COM1"
print gogo:ping
```

On Linux:

```
gogo:open "/dev/ttyS01"
print gogo:ping
```

For more information on NetLogo extensions, see the Extensions Guide.

Models saved as applets (using "Save as Applet" on NetLogo's File menu) cannot use the Gogo extension, since applets can't use extensions that require additional extra jars. (Also, unsigned applets aren't allowed to access external devices anyway.) For examples that use the GoGo extension, see the GoGo section under Code Examples in NetLogo's Models Library.

Primitives

gogo:close gogo:open gogo:open? gogo:ports gogo:output−port−coast gogo:output−port−off gogo:output−port−reverse gogo:output−port−[that|this]way gogo:ping gogo:sensor gogo:set−output−port−power gogo:talk−to−output−ports

gogo:close

gogo:close

Close the connection to the GoGo Board.

See also gogo:open and gogo:open?.

gogo:open

gogo:open *port−name*

Open a connection to the GoGo Board connected to serial port named *port−name*. See gogo:ports for more information about port names.

If the GoGo Board is not responding, or you attempt to open a port without a GoGo Board connected to it, an error will be generated.

Example:

```
gogo:open "COM1"
```

See also gogo:open? and gogo:close.

gogo:open?

gogo:open?

Reports true if there is a connection to a GoGo board open. Reports false otherwise.

gogo:ports

gogo:ports

Reports a list of serial port names which a GoGo Board **may** be connected to. On certain computers, you might get a list of two or three different serial ports. In that case, try to open each of them until the connection is successful.

gogo:output−port−coast

gogo:output−port−coast

Turns off the power of the active ports. When attached to motors, does not apply a braking force as gogo:output−port−off does. Therefore, the motor will gradually slow down before stopping completely. This will have the same effect as gogo:output−port−off on most output devices other than motors. The output−ports effected by this command are determined by the gogo:talk−to−output−ports command.

The following code will will turn on output port a for 1 second, and then stop the motor gradually:

```
gogo:talk−to−output−ports ["a"]
gogo:output−port−on
wait 1
gogo:output−port−coast
```

gogo:output−port−off

gogo:output−port−off

Turns off power to the output ports. If using motors, a braking force is applied. The output ports effected by this command are determined by the gogo:talk−to−output−ports command.

gogo:output−port−reverse

gogo:output−port−reverse

Reverses the direction of the output ports. The output ports effected by this command are determined by the gogo:talk−to−output−ports command.

gogo:output−port−[that/this]way

gogo:output−port−thatway

gogo:output−port−thisway

Apply power to the output port in a given direction. Output ports can be powered in two directions, arbitrarily called *thisway* and *thatway*. The output−ports effected by the command are determined by the gogo:talk−to−output−ports command. Note that this is different from gogo:output−port−reverse because *thisway* and *thatway* will always be the same direction provided the connector's polarity is the same.

gogo:talk−to−output−ports

gogo:talk−to−output−ports *output−portlist*

This command will set the corresponding output ports as active. They will be the ones affected by the commands such as gogo:output−port−on and gogo:output−port−off. The user can "talk" to one or multiple ports at the same time. Output ports are typically connected to motors, but you could also use bulbs, LEDs and relays. Output ports are identified by one letter names: "a", "b", "c", and "d".

Examples:

```
;; talk to all output−ports
gogo:talk−to−output−ports [ "a" "b" "c" "d" ]
;; will give power to all output−ports
gogo:output−port−on

;; talk to output−ports A and D
gogo:talk−to−output−ports [ "a" "d" ]
;; will turn off output−ports A and D.
;; The other output−ports will keep
;; their current state
gogo:output−port−off

gogo:talk−to−output−ports [ "c" "b" ]
;; turn off remaining output−ports
gogo:output−port−off
```

gogo:ping

gogo:ping

Checks the status of GoGo board. This is mostly used to make sure the board is connected to the correct serial port. It reports true if the GoGo Board responds to a diagnostic message, and false otherwise.

Example:

```
print gogo:ping
```

gogo:sensor

gogo:sensor *sensor*

Reports the value of the sensor named *sensor* as a number. Sensors are named by numbers 1 to 8. Value ranges between 0−1023. 1023 is returned when there is no sensor attached to the port (highest resistance), or when the sensor is an "open" state. Zero is returned when the sensor is short circuited (no resistance).

Examples:

```
print gogo:sensor 1
;; prints the value of sensor 1

foreach [ 1 2 3 4 5 6 7 8 ]
  [print (word "Sensor " ? " = " gogo:sensor ?)]
;; prints the value of all sensors

if gogo:sensor 1 < 500 [ ask turtles [ fd 10 ]]

;; will move all turtles 10 steps forward if sensor 1's value is less than 500.

loop [if gogo:sensor 1 < 500 [ ask turtles [ fd 10 ] ] ]

;; will continuously check sensor 1's value and
;; move all turtles 10 steps forward every time
;; that the sensor value is less than 500.
```

gogo:set−output−port−power

gogo:set−output−port−power *power−level*

Sets the power level of the active output ports. *power−level* is a number between 0 (off) and 7 (full−power). The output−ports effected by those command are determined by the gogo:talk−to−output−ports command. Note that for many practical applications it is more efficient to use mechanical devices, such as gears and pulleys, to control the torque of motors.

Example:

```
gogo:talk−to−motors ["a" "b" "c" "d"]
gogo:set−motor−power 4
;; will lower the power of all output ports by half of the full power .
```

Profiler Extension

The Profiler Extension provides information which may help you make your model run faster. It consists of a set of primitives for measuring how many times the procedures in your model are called during a run and how long each call takes.

Caveats

Note on compatibility: The extension requires that you use Java 1.5 or greater when running NetLogo, as it uses features not present in Java 1.4. On Windows you should be fine since the NetLogo download includes Java 1.5. Mac users must have Mac OS X 10.4 or later, since Apple does not offer Java 1.5 on 10.2 or 10.3.

Caution! The Profiler Extension is new and experimental. It is not yet well tested or user friendly. Nonetheless, we think some users will find it useful.

Usage

The profiler extension comes preinstalled. To use the extension in your model, add a line to the top of your procedures tab:

```
extensions [profiler]
```

If your model already uses other extensions, then it already has an `extensions` line in it, so just add `profiler` to the list.

For more information on using NetLogo extensions, see the Extensions Guide.

For examples that use the profiler extension, see the Profiler Example model under Code Examples in the NetLogo Models Library.

Primitives

profiler:calls profiler:exclusive−time profiler:inclusive−time profiler:start profiler:stop profiler:reset profiler:report

profiler:calls

profiler:calls *procedure−name*

Reports the number of times that *procedure−name* was called. If *procedure−name* is not defined, then reports 0.

profiler:exclusive−time

profiler:exclusive−time *procedure−name*

Reports the exclusive time, in milliseconds, that *procedure−name* was running for. Exclusive time is the time from when the procedure was entered, until it finishes, but does not include any time spent in other user−defined procedures which it calls.

If *procedure−name* is not defined, then reports 0.

profiler:inclusive−time

profiler:calls *procedure−name*

Reports the inclusive time, in milliseconds, that *procedure−name* was running for. Inclusive time is the time from when the procedure was entered, until it finishes.

If *procedure−name* is not defined, then reports 0.

profiler:start

profiler:start

Instructs the profiler to begin recording user−defined procedure calls.

profiler:stop

profiler:stop

Instructs the profiler to stop recording user−defined procedure calls.

profiler:reset

profiler:reset

Instructs the profiler to erase all collected data.

profiler:report

profiler:report

Reports a string containing a breakdown of all user−defined procedure calls. The `Calls` column contains the number of times a user−defined procedure was called. The `Incl T(ms)` column is the total time, in milliseconds, it took for the call to complete, including the time spent in other user−defined procedures. The `Excl T(ms)` column is the total time, in milliseconds, spent within that user−defined procedure, not counting other user−define procedures it called. The `Excl/calls` column is an estimate of the time, in milliseconds, spent in that user−defined procedure for each call.

Here is example output:

```
Sorted by Exclusive Time
```

```
Name                                Calls Incl T(ms) Excl T(ms) Excl/calls
CALLTHEM                               13     26.066     19.476      1.498
CALLME                                 13      6.413      6.413      0.493
REPORTME                               13      0.177      0.177      0.014

Sorted by Inclusive Time
Name                                Calls Incl T(ms) Excl T(ms) Excl/calls
CALLTHEM                               13     26.066     19.476      1.498
CALLME                                 13      6.413      6.413      0.493
REPORTME                               13      0.177      0.177      0.014

Sorted by Number of Calls
Name                                Calls Incl T(ms) Excl T(ms) Excl/calls
CALLTHEM                               13     26.066     19.476      1.498
```

FAQ (Frequently Asked Questions)

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you. Please send comments, suggestions, and questions to feedback@ccl.northwestern.edu, and bug reports to bugs@ccl.northwestern.edu.

Questions

General

- **Why is it called NetLogo?**
- **How do I cite NetLogo in an academic publication?**
- **How do I cite a model from the Models Library in an academic publication?**
- **Where and when was NetLogo created?**
- **What programming language was NetLogo written in?**
- **What's the difference between StarLogo, MacStarLogo, StarLogoT, and NetLogo?**
- **What license is NetLogo released under? Are there are any legal restrictions on use, redistribution, etc.?**
- **Is the source code to NetLogo available?**
- **Do you offer any workshops or other training opportunities for NetLogo?**
- **Are there any NetLogo textbooks?**
- **Is NetLogo available in a Spanish version, German version, (your language here) version, etc.?**
- **Is NetLogo compiled or interpreted?**
- **Has anyone built a model of <x>?**
- **Are NetLogo models runs scientifically reproducible?**
- **Will NetLogo and NetLogo 3D remain separate?**

Downloading

- **The download form doesn't work for me. Can I have a direct link to the software?**
- **Downloading NetLogo takes too long. Is it available any other way, such as on a CD?**
- **I downloaded and installed NetLogo but the Models Library has few or no models in it. How can I fix this?**
- **Can I have multiple versions of NetLogo installed at the same time?**
- **I'm on a UNIX system and I can't untar the download. Why?**
- **How do I install NetLogo unattended?**
- **I installed the without VM option now I get an error message saying NetLogo can't find server.dll.**

Applets

- **I tried to run one of the applets on your site, but it didn't work. What should I do?**
- **Can I make my model available as an applet while keeping the code secret?**
- **Can a model saved as an applet use `import-world`, `file-open`, and other commands that read files?**
- **When running my model as an applet, I get the following error: java.lang.OutOfMemoryError: Java heap space.**

- When I tried loading my model as an applet I get an error like: java.lang.ClassFormatError: Incompatible magic value.

Running

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- Why is NetLogo so much slower when I unplug my Windows laptop?
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- Can I run NetLogo from the command line, without the GUI?
- Does NetLogo take advantage of multiple processors/cores?
- Can I distribute NetLogo model runs across a cluster of computers?
- I want to try HubNet. Can I?

Usage

- When I move the speed slider all the way to the right, why does my model seem to stop?
- How do I change how many patches there are?
- Can I use the mouse to "paint" in the view?
- How big can my model be? How many turtles, patches, procedures, buttons, and so on can my model contain?
- Can I import GIS data into NetLogo?
- Can I have more than one model open at a time?
- Can I change the choices in a chooser on the fly?
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- How is the NetLogo language different from the StarLogo and StarLogoT languages? How do I convert my StarLogo or StarLogoT model to NetLogo?
- How does the NetLogo language differ from other Logos?
- How come my model from an earlier NetLogo doesn't work right?
- Why does my code have strange characters in it?
- Why do I get a runtime error when I use `setxy random world-width random world-height`? It worked before.
- How do I take the negative of a number?
- My turtle moved forward 1, but it's still on the same patch. Why?
- How do I keep my turtles on patch centers?
- `patch-ahead 1` is reporting the same patch my turtle is already standing on. Why?
- How do I give my turtles "vision"?
- Can agents sense what's in the drawing layer?
- I'm getting numbers like 0.10000000004 and 0.799999999999 instead of 0.1 and 0.8. Why?
- The documentation says that `random-float 1.0` might return 0.0 but will never return 1.0. What if I want 1.0 to be included?
- How can I use different patch "neighborhoods" (circular, Von Neumann, Moore, etc.)?
- How can I keep two turtles from occupying the same patch?
- How can I find out if a turtle is dead?
- Does NetLogo have arrays?

- **Does NetLogo have hash tables or associative arrays?**
- **How can I convert an agentset to a list, or vice versa?**
- **How do I stop foreach?**

BehaviorSpace

- **How do I gather data every n ticks?**
- **I'm varying a global variable I declared in the Procedures tab, but it doesn't work. Why?**
- **Why are some of my results cut off in Excel?**

Extensions

- **I'm writing an extension. Why does the compiler say it can't find org.nlogo.api?**

General

Why is it called NetLogo?

The "Logo" part is because NetLogo is a dialect of the Logo language.

"Net" is meant to evoke the decentralized, interconnected nature of the phenomena you can model with NetLogo, including network phenomena. It also refers to HubNet, the multiuser participatory simulation environment included in NetLogo.

How do I cite NetLogo in an academic publication?

NetLogo itself: Wilensky, U. 1999. NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer−Based Modeling, Northwestern University. Evanston, IL.

HubNet: Wilensky, U. & Stroup, W., 1999. HubNet. http://ccl.northwestern.edu/netlogo/hubnet.html. Center for Connected Learning and Computer−Based Modeling, Northwestern University. Evanston, IL.

How do I cite a model from the Models Library in a publication?

The correct citation is included in the CREDITS AND REFERENCES section of every model's Information tab.

Where and when was NetLogo created?

NetLogo was first created in 1999 by Uri Wilensky at the Center for Connected Learning and Computer−Based Modeling, then at Tufts University in the Boston area. NetLogo grew out of StarLogoT, which was authored by Wilensky in 1997. In 2000, the CCL moved to Northwestern University, in the Chicago area. NetLogo 1.0 came out in 2002, 2.0 in 2003, 3.0 in 2005, and 4.0 in 2007.

What programming language was NetLogo written in?

NetLogo is written entirely in Java (version 1.4.1).

What's the difference between StarLogo, MacStarLogo, StarLogoT, and NetLogo?

The original StarLogo was developed at the MIT Media Lab in 1989−1990 and ran on a massively parallel supercomputer called the Connection Machine. A few years later (1994), a simulated parallel version was developed for the Macintosh computer. That version eventually became MacStarLogo. StarLogoT (1997), developed at the Center for Connected Learning and Computer−Based Modeling (CCL), is essentially an extended version of MacStarLogo with many additional features and capabilities.

Since then two multi−platform Java−based multi−agent Logos have been developed: NetLogo (from the CCL) and a Java−based version of StarLogo (from MIT).

The NetLogo language and environment differ in many respects from MIT StarLogo's. Both languages were inspired by the original StarLogo, but were redesigned in different ways. NetLogo's design was driven by the need to revise and expand the language so it is easier to use and more powerful, and by the need to support the HubNet architecture. NetLogo incorporates almost all of the extended functionality of our earlier StarLogoT, as well as a great many newer features.

What license is NetLogo released under? Are there are any legal restrictions on use, redistribution, etc.?

The license is given in the "Copyright" section of the NetLogo User Manual, as well as in the application's about box and the README file accompanying the download.

A quick summary of the license is that use is unrestricted, including commercial use, but there are some restrictions on redistribution and/or modification (unless you contact Uri Wilensky to arrange different terms).

We are in the process of reevaluating the language of the license in response to user feedback. In the future, we intend to send out a revised license.

Is the source code to NetLogo available?

At present, no. We are working on eventually releasing the source under an open source license.

In the meantime, though, NetLogo is not a closed platform. We provide an API for controlling NetLogo from external Java code and an API for users to write new commands and reporters in Java. (See "Controlling" and "Extensions" in the User Manual.) We encourage users to write NetLogo extensions and share them with the NetLogo user community.

Do you offer any workshops or other training opportunities for NetLogo?

We offer workshops from time to time. If a workshop has been scheduled, we will announce it on the NetLogo home page and on the netlogo−users group. If interested in this type of opportunity, please contact us at feedback@ccl.northwestern.edu.

Are there any NetLogo textbooks?

We at the CCL have hoped to write several NetLogo textbooks for quite some time. These could be aimed at different audiences, such as: middle school, high school, undergraduate course in modeling or complexity, practical guide for interested adults.

Unfortunately, we have not yet been able to find the time to make these happen. If anyone from the user community would like to collaborate on such a venture, please let us know. We would welcome it.

Is NetLogo available in a Spanish version, German version, (your language here) version, etc.?

At present, NetLogo is available only in English.

We plan to eventually make it possible for users to produce their own foreign−language "packs" for NetLogo and share them with each other. In order to do this, we need to separate all of the English text from the rest of the source code, so that is separately editable. We're not sure when this will happen.

Is NetLogo compiled or interpreted?

Short answer: partially compiled; we are working towards a full compiler.

Long answer: NetLogo does include a compiler that generates Java byte code. However, this compiler does not yet support the entire language, so some parts of user code are interpreted. We are working on expanding the compiler to support the entire language. Note that our compiler generates Java byte code, and Java virtual machines have "just−in−time" compilers that in turn compile Java byte code all the way to native code, so user code is ultimately translated to native code.

Has anyone built a model of <x>?

The best place to ask this question is on the NetLogo Users Group.

You should also check the Community Models section of our Models Library web page.

Are NetLogo models runs scientifically reproducible?

Yes. NetLogo's agent scheduling algorithms are deterministic, and NetLogo always uses Java's "strict math" library, which gives bit−for−bit identical results regardless of platform. But keep the following cautions in mind:

- If your model uses random numbers, then in order to get reproducible behavior, you must use the `random-seed` command to set the random seed in advance, so that your model will

receive the exact same sequence of random numbers every time. Remember that agentsets are always in random order, so anything you do with agentsets uses random numbers.
- If your model uses the `every` or `wait` commands in such a way that affects the outcome of the model, then you may get different results on different computers, or even on the same computer, since the model may run at a different speed. (Such models are rare. These two commands are common, but using them in a way that affects the outcome is not.)
- In order to reproduce model runs exactly, you must be using the exact same version of NetLogo. The details of the agent scheduling mechanism and the random number generator may change between NetLogo versions, and other changes (bugfixes in the engine, language changes, and so forth) may also affect the behavior of your model. (Then again, they may not.)
- We have expended every effort to make NetLogo model runs fully reproducible, but of course this can never truly be an iron−clad guarantee, due not only to the possibility of random hardware failure, but also the possibility of human error in the design of: your model, NetLogo, your Java VM, your hardware, and so on.

Will NetLogo and NetLogo 3D remain separate?

No. The split is temporary. Eventually a single unified version of NetLogo will support both 2D and 3D modeling. We will be sure to design the 3D world support in such a way that it doesn't get in the way when you are building 2D models.

Models built in NetLogo 3D preview releases may require changes in order to run in the eventual unified version.

Downloading

The download form doesn't work for me. Can I have a direct link to the software?

Please write us at bugs@ccl.northwestern.edu and we'll either fix the problem with the form, or provide you with an alternate method of downloading the software.

Downloading NetLogo takes too long. Is it available any other way, such as on a CD?

At present, no. If this is a problem for you, contact us at feedback@ccl.northwestern.edu.

I downloaded and installed NetLogo but the Models Library has few or no models in it. How can I fix this?

So far, users reporting this problem all used the "without VM" download option for Windows. Uninstall NetLogo and try the "with VM" download instead.

Even if the "with VM" download fixes it for you, please contact us at bugs@ccl.northwestern.edu so we can find out more details about your setup. We'd like to fix this in a future version, but to troubleshoot it we need help from users.

Can I have multiple versions of NetLogo installed at the same time?

Yes. When you install NetLogo, the folder that is created contains has the version number in its name, so multiple versions can coexist.

On Windows systems, whichever version you installed last will be the version that opens when you double click a model file in Windows Explorer. On Macs, you can control what version opens via "Get Info" in the Finder.

I'm on a UNIX system and I can't untar the download. Why?

Some of the files in the tarball have very long pathnames, too long for the standard tar format. You must use the GNU version of tar instead (or another program which understands the GNU tar extensions). On some systems, the GNU version of tar is available under the name "gnutar". You can find out if you are already using the GNU version by typing `tar --version` and seeing if the output says "tar (GNU tar)".

How do I install NetLogo unattended?

It depends on which platform you are using.

- **Linux:** Untar NetLogo into the appropriate place. Optionally, add your own shell script to cd into the NetLogo directory and call java on the NetLogo.jar. For example (assuming you copied the netlogo distribution into `/opt/netlogo`):

```
#!/bin/bash
(cd /opt/netlogo/; /usr/local/sun/jdk1.5.0/bin/java -jar NetLogo.jar $@)
```

- **Mac:** Copy the NetLogo directory from the disk image into the Applications folder.
- **Windows:** There are two possible approaches.

  NetLogo uses InstallAnywhere, which has a silent install mode. You have to make properties file with the same name as the installer executable, and it should contain the following, with values to reflect your preferences and the version you are installing.:

```
USER_INSTALL_DIR=/programs/NetLogoX.Y/
INSTALLER_UI=silent
```

  Another approach is to install NetLogo and then copy the resulting directory onto other machines. Unfortunately, NetLogo will not appear in the Start menu, nor will `.nlogo` files will not start NetLogo automatically when you double-click them. However, Anders Martinusen writes:

```
Also found that is possible to export a few keys from the windows
registry into a .reg file. This file can then be pushed out on the
target machines along with the files. This will solve the issue about
double clicking the .nlogo files. It also gives the possibility to later
on uninstall the program from the Control Panel.

The content of the reg file is:

[HKEY_CLASSES_ROOT\.nlogo]
@="NetLogoModelFile"
```

```
[HKEY_CLASSES_ROOT\NetLogoModelFile]
@="NetLogo model file"

[HKEY_CLASSES_ROOT\NetLogoModelFile\DefaultIcon]
@="%TARGET_PATH%\\Model icon.ico,0"

[HKEY_CLASSES_ROOT\NetLogoModelFile\shell\open\command]
@="\"%TARGET_PATH%\\NetLogo 3.0.2.exe\" --launch \"%1\""

[HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Uninstall\NetLogo
3.0.2]
"DisplayName"="NetLogo 3.0.2"
"UninstallString"="\"%TARGET_PATH%\\UninstallerData\\Uninstall
NetLogo.exe\""
```

I installed the without VM option and now I get an error message saying NetLogo can't find server.dll.

NetLogo uses a special option called the "server" VM which requires the JVM rather than just the JRE, see the requirements section for details.

Applets

I tried to run one of the applets on your site, but it didn't work. What should I do?

Current versions of NetLogo require that your web browser support Java 1.4.1 or higher. For more details about Java requirements see the Applet guide

Some NetLogo applets may require more memory than the browser normally makes available. See the memory section of the Applet guide for details on how to change the memory allocation.

Can I make my model available as an applet while keeping the code secret?

No. In order for the applet to operate, the model file must be accessible also.

When you use "Save as applet" on the File menu, the HTML page generated contains a link where the user can download the model file. If you want, you can remove that link. Doing so will make it harder for the user to access the model file, but not impossible.

Can a model saved as an applet use `import-world`, `file-open`, and other commands that read files?

Yes, but only to read files that are stored in the same directory on your web server as the HTML and model files. Applets cannot read files on the user's computer, only the web server.

When running my model as an applet, I get the following error: java.lang.OutOfMemoryError: Java heap space

The Java Plug−In is not allocating sufficient space to run the model. Details on how big a model can be in NetLogo can be found here. You will need to increase the amount of memory available to the Java Plug−In. See the instructions here

When I tried loading my model as an applet I get an error like: java.lang.ClassFormatError: Incompatible magic value.

If your web server returns custom error messages in response to requests for non−existent pages it must also return a status code of 404 Not Found, otherwise, NetLogo thinks the following data is what it requested and tries to read it as such. This happens even if all the files required to run the applet are present.

If you don't have control over the error messages on your web server you can use the following as a workaround:

- Create a directory named `META−INF` in the same directory as the applet files.
- Create a subdirectory of `META−INF` called `services`
- Create a file called `org.apache.commons.logging.LogFactory` in the `services` subdirectory
- Add the following line to `org.apache.commons.logging.LogFactory`:

```
org.apache.commons.logging.impl.LogFactoryImpl
```

Note that all the directory and file names are case sensitive and should be created exactly as written.

Running

Can I run NetLogo from a CD?

Yes. NetLogo runs fine on a read−only file system.

Why is NetLogo so much slower when I unplug my Windows laptop?

Your computer is switching to power saving mode when unplugged. It's normal for this to reduce speed a little, but unfortunately there is a bug in Java that drastically slows down Swing applications, including NetLogo.

One workaround is to change the power settings on your computer so it doesn't go into power saving mode when you unplug it. (If you do this, your battery won't last as long.)

Another workaround is to run NetLogo with an option recommended by Sun, by editing the NetLogo.lax file, found in the NetLogo directory (under Program Files on your hard drive, unless you installed NetLogo in a different location). Edit this line:

```
lax.nl.java.option.additional=−Djava.ext.dirs= −server −Dsun.java2d.noddraw=true
```

and add `-Dsun.java2d.ddoffscreen=false` at the end of the last line.

You can see the details of the Java bug and vote for Sun to fix it here.

How come NetLogo won't start up on my Linux machine?

Ideally, any Java runtime version 1.4.1 or greater will run NetLogo. However, some Java implementations do not support features which NetLogo uses, such as Java2D and Swing. An example is the GNU libgcj based runtime on Linux, which comes preinstalled on some Linux distributions; NetLogo does not work with this runtime.

We recommend the Sun or IBM Java runtimes when using NetLogo on Linux.

Can I run NetLogo from the command line, without the GUI?

Yes. The easiest way is to set up your model run as a BehaviorSpace experiment. No additional programming is required. See the BehaviorSpace section of the User Manual for details.

Another option is to use our Controlling API. Some light Java programming is required. See the "Controlling" section of the User Manual for details and sample code.

Does NetLogo take advantage of multiple processors/cores?

Not for a single model run, no. The NetLogo engine is single threaded and we expect it to remain that way. We don't have any plans to make it possible to split a single model run across multiple processors or multiple computers.

One way to take advantage of multiple processors, or multi-core processors, to do multiple model runs concurrently by running more than one instance of NetLogo simultaneously, each in its own Java virtual machine:

- To run more than one copy of the full NetLogo application at once, see this answer for instructions.
- You can also run models from the command line using BehaviorSpace or the Controlling API, and start up as many separate headless NetLogo processes simultaneously as you want.

In a future version of NetLogo, we hope to improve the support for multiple processors/cores as follows:

- Allow multiple models to be open simultaneously, each running in a different thread and hence on a different processor/core.
- Modify BehaviorSpace to optionally do multiple model runs in parallel in a configurable number of separate threads, so the runs would be spread across available processors/cores.

Can I distribute NetLogo model runs across a cluster of computers?

Many of the same comments in the previous answer apply. It is not possible to split a single model run across multiple computers, but you can have each machine in a cluster doing one or more

separate, independent model runs, using either BehaviorSpace or our Controlling API.

Numerous users are already using NetLogo on clusters. You can seek them out on the NetLogo Users Group.

I want to try HubNet. Can I?

Yes. There are two types of HubNet available. With Computer HubNet, participants run the HubNet Client application on computers connected by a regular computer network. In Calculator HubNet, created in conjunction with Texas Instruments, participants use Texas Instruments graphing calculators and the TI−Navigator Classroom Learning System.

See the HubNet section of the user manual for more details on Calculator HubNet for TI−Navigator.

For more information on HubNet in general, see the HubNet Guide.

Usage

When I move the speed slider all the way to the right, why does my model seem to stop?

The only way NetLogo can make your model run faster is by updating the view less frequently. As you move the speed slider to the right, view updates become less and less frequent. Since view updates take time, that means more speed.

However, fewer updates also means that the updates come farther apart. When several seconds pass between updates, it may seem like your model has stopped. It hasn't. It's running at full speed. Watch the tick counter! (If your model uses it. If it doesn't, watch something else, such as a plot.)

To get a feel for what's going, it may help to gradually move the slider to the right, rather than moving it all the way to the right all at once. If you find the updates too infrequent at the rightmost position, don't push the slider that far.

How do I change how many patches there are?

Press the Settings... button in the toolbar on the Interface tab. A dialog will appear in which you may change the dimensions of the world.

A quicker method is to use the three sets of black arrows in the upper left corner of the 2D view.

Can I use the mouse to "paint" in the view?

NetLogo does not have a built−in set of painting tools for painting in the view. But with only a few lines of code, you can add painting capability to your model. To see how it's done, look at Mouse Example, in the Code Examples section of the Models Library. The same techniques can be used to let the user interact with your model using the mouse in other ways, too.

Another possibility is to use a special drawing model such as the Drawing Tool model by James Steiner which is available from http://ccl.northwestern.edu/netlogo/models/community/.

A third possibility is to create an image in another program and import it. See the answer to Can I import a graphic into NetLogo?.

How big can my model be? How many turtles, patches, procedures, buttons, and so on can my model contain?

We have tested NetLogo with models that use hundreds of megabytes of RAM and they work fine. We haven't tested models that use gigabytes of RAM, though. Theoretically it should work, but you might hit some limits that are inherent in the underlying Java VM and/or operating system (either designed−in limits, or bugs).

The NetLogo engine has no fixed limits on size. On Macintosh and Windows operating systems, though, by default NetLogo ships with a one−gigabyte ceiling on how much total RAM it can use. (On other operating systems the ceiling is determined by your Java VM.)

Here's how to raise the limit if you need to:

- **Windows:** Edit this section of the "NetLogo.lax" file in the NetLogo folder:

  ```
  # LAX.NL.JAVA.OPTION.JAVA.HEAP.SIZE.MAX
  # ------------------------------------
  # allow the heap to get huge
  lax.nl.java.option.java.heap.size.max=536870912
  ```

  Note: this might not help on some Windows 98 or Windows ME systems.
- **Macintosh:** Edit the Contents/Info.plist file in the NetLogo application package. (You can reach this file by control−clicking the application in the Finder and choosing "Show Package Contents" from the popup menu.) The relevant section is this; the second number is the ceiling:

  ```
  <key>VMOptions</key>
  <string>−Xms16M −Xmx1024M</string>
  ```

  Note that (at least as of Mac OS X 10.3), the maximum possible heap size for any Java program is two gigabytes.
- **Other:** Java VMs from Sun let you set the ceiling on the command line as follows. If you are using a VM from a different vendor, the method may be different. Note that we recommend the `−server` flag for best performance in most situations. We also recommend setting the noddraw option to true when using the GUI as Direct Draw can conflict with OpenGL.

  ```
  java −server −Dsun.java2d.noddraw=true −Xms16M −Xmx1024M −jar NetLogo.jar
  ```

Can I import GIS data into NetLogo?

Yes, a number of users have constructed models using raster GIS data. (We don't know of users who have used vector GIS data, other than by converting it to raster data first.)

One simple way is to use `import−pcolors`, but that only works for importing maps that are images, not maps in other formats.

We do not have built−in support for reading common GIS formats. However, a number of our users are working with GIS data successfully using NetLogo code that reads GIS data using our file I/O primitives such as `file−open`.

It is also possible to use external software to convert GIS data into a format that is easier to read from NetLogo than the original format. This has been discussed on the NetLogo Users Group several times. We encourage users interested in using NetLogo for GIS applications to share their questions and experiences with the group.

My model runs slowly. How can I speed it up?

Here's some ways to make it run faster without changing the code:

- Edit the forever buttons in your model and turn off the "Force view update after each run" checkbox. This allows the view to skip frames, which may speed up models which are graphics−intensive. (See the Buttons section of the Programming Guide for a discussion of this.)
- Use the freeze switch in the view control strip to freeze the view entirely. (Some models spend most of their time updating the view.)
- If your model is using all available RAM on your computer, then installing more RAM should help. If your hard drive makes a lot of noise while your model is running, you probably need more RAM.
- Use turtle size 1, 1.5, or 2 as these sizes are cached by NetLogo.

In many cases, though, if you want your model to run faster, you may need to make some changes to the code. Usually the most obvious opportunity for speedup is that you're doing too many computations that involve all the turtles or all the patches. Often this can be reduced by reworking the model so that it does less computation per time step. If you need help with this, if you contact us at feedback@ccl.northwestern.edu we may be able to help if you can send us your model or give us some idea of how it works. The members of the NetLogo Users Group may be able to help as well.

Note that using `run` and `runresult` are much slower than running code directly; you should avoid using these primitives in performance−critical code.

Can I have more than one model open at a time?

One instance of NetLogo can only have one model open at a time. (We plan to change this in a future version.)

You can have multiple models open by opening multiple instances of NetLogo, though. On Windows and Linux, simply start the application again. On a Mac, you'll need to duplicate the application in the Finder, then open the copy. (The copy takes up only a very small amount of additional disk space.)

Can I change the choices in a chooser on the fly?

At present, no. In a future version of NetLogo, we plan to support this.

Can I divide the code for my model up into several files?

Yes, this is available on an experimental basis using the `__includes` keyword.

How do I show the legend in a plot?

Click the word "Pens" in the upper right corner of the plot. The legend will include any pens that have the "Show in Legend" option checked when editing the plot. Clicking "Pens" again will hide the legend.

Programming

How is the NetLogo language different from the StarLogo and StarLogoT languages? How do I convert my StarLogo or StarLogoT model to NetLogo?

We don't have a document that specifically summarizes the differences between these programs. If you have built models in StarLogo or StarLogoT before, then we suggest reading the Programming Guide section of this manual to learn about NetLogo, particularly the sections on "Ask" and "Agentsets". Looking at some of the sample models and code examples in the Models Library may help as well.

If you need any help converting your StarLogo or StarLogoT model to NetLogo, please feel free to seek help on the NetLogo Users Group. You may also ask us for help at feedback@ccl.northwestern.edu.

How does the NetLogo language differ from other Logos?

There is no standard definition of Logo; it is a loose family of languages. We believe that NetLogo shares enough syntax, vocabulary, and features with other Logos to earn the Logo name.

Still, NetLogo differs in some respects from most other Logos. The most important differences are as follows.

Surface differences:

- The precedence of mathematical operators is different. Infix math operators (like `+`, `*`, etc.) have lower precedence than reporters with names. For example, in many Logos, if you write `sin x + 1`, it will be interpreted as `sin (x + 1)`. NetLogo, on the other hand, interprets it the way most other programming languages would, and the way the same expression would be interpreted in standard mathematical notation, namely as `(sin x) + 1`.
- The `and` and `or` reporters are special forms, not ordinary functions, and they "short circuit", that is, they only evaluate their second input if necessary.
- Procedures can only be defined in the Procedures tab, not interactively in the Command Center.
- Reporter procedures, that is, procedures that "report" (return) a value, must be defined with `to-report` instead of `to`. The command to report a value from a reporter procedure is `report`, not `output`.

- When defining a procedure, the inputs to the procedure must be enclosed in square brackets, e.g. `to square [x]`.
- Variable names are always used without any punctuation: always `foo`, never `:foo` or `"foo`. (To make this work, instead of a `make` command taking a quoted argument we supply a `set` special form which does not evaluate its first input.) As a result, procedures and variables occupy a single shared namespace.

The last three differences are illustrated in the following procedure definitions:

most Logos	NetLogo

`to square :x`
`output :x * :x`
`end`
	`to-report square [x]`
	`report x * x`
	`end`

Deeper differences:

- NetLogo is lexically scoped, not dynamically scoped.
- NetLogo has no "word" data type (what Lisp calls "symbols"). Eventually, we may add one, but since it is seldom requested, it may be that the need doesn't arise much in agent-based modeling. We do have strings. In most situations where traditional Logo would use words, we simply use strings instead. For example in Logo you could write `[see spot run]` (a list of words), but in NetLogo you must write `"see spot run"` (a string) or `["see" "spot" "run"]` (a list of strings) instead.
- NetLogo's `run` command works on strings, not lists (since we have no "word" data type), and does not permit the definition or redefinition of procedures.
- Control structures such as `if` and `while` are special forms, not ordinary functions. You can't define your own special forms, so you can't define your own control structures. (NetLogo's `run` command is no help here.)
- As in most Logos, functions as values are not supported. Most Logos provide similar if less general functionality, though, by allowing passing and manipulation of fragments of source code in list form. NetLogo's capabilities in this area are presently limited. A few of our built-in special forms use UCBLogo-style ``templates'' to accomplish a similar purpose, for example, `sort-by [length ?1 < length ?2] string-list`. In some circumstances, using `run` and `runresult` instead is workable, but unlike most Logos they operate on strings, not lists.

Of course, the NetLogo language also contains many additional features not found in most other Logos, most importantly agents and agentsets.

How come my model from an earlier NetLogo doesn't work right?

See the Transition Guide section of the User Manual for help.

Why does my code have strange characters in it?

NetLogo only works in "en" locales. A locale is a setting which tells NetLogo which language you are using, as well as how to display dates and numbers. You may need to switch to to an English locale before launching NetLogo. This is usually done in the "Regional Settings" or "Internationalization" panel of the operating system.

In a future version of NetLogo we plan to support different languages and locales.

Why do I get a runtime error when I use `setxy random world-width random world-height`? It worked before.

Many models made in NetLogo 3.0 or earlier use this code to scatter turtles randomly, using either `random` or `random-float`. It only works if world wrapping is on.

(Why? Because when wrapping is on, you can set coordinates of turtles to numbers beyond the edge of the world and NetLogo will wrap the turtle to the other side. But in worlds that don't wrap setting the x or y coordinates of a turtle to a point outside the bounds of the world causes a runtime error. The world wrap settings were added in NetLogo 3.1. See the Topology section of the Programming Guide for more information.)

To fix your model so that it works regardless of the wrapping settings, use one of these two commands instead:

```
setxy random-xcor random-ycor
setxy random-pxcor random-pycor
```

The two commands are a bit different. The first command puts the turtle on a random point in the world. The second command puts the turtle on the center of a random patch. An even more concise way to put a turtle on the center of a random patch is:

```
move-to one-of patches
```

How do I take the negative of a number?

Any of these ways:

```
(- x)
-1 * x
0 - x
```

With the first way, the parentheses are required.

My turtle moved forward 1, but it's still on the same patch. Why?

Moving forward 1 is only guaranteed to take a turtle to a new patch if the turtle's heading is a multiple of 90 (that is, exactly north, south, east, or west).

It's because the turtle might not be standing in the center of a patch. It might be near a corner. For example, suppose your turtle is close to the southwest corner of a patch and is facing northeast. The length of the patch diagonal is 1.414... (the square root of two), so `fd 1` will leave the turtle near the northeast corner of the same patch.

If you don't want to have to think about these issues, one possibility is to write your model in such a way that your turtles always come to rest on patch centers. See next question.

How do I keep my turtles on patch centers?

A turtle is on a patch center when its `xcor` and `ycor` are integers.

You can move a turtle to the center of its current patch with either of these two equivalent commands:

```
move-to patch-here
setxy pxcor pycor
```

But you'll never need to do that if you never allow turtles off of patch centers in the first place.

The `sprout` command creates turtles on patch centers. For example:

```
ask n-of 50 patches [ sprout 1 [ face one-of neighbors4 ] ]
```

Another way for a turtle to start on a patch center is with a command such as this line of turtle code, which moves it to the center of a random patch:

```
move-to one-of patches
```

Once a turtle is on a patch center, as long as its heading always stays an exact multiple of 90 (that is to say, due north, east, south, or west), and as it long as it moves forward or back by integer amounts, it will always land on patch centers.

See Random Grid Walk Example, in the Code Examples section of the Models Library, to see these code snippets in use.

`patch-ahead 1` is reporting the same patch my turtle is already standing on. Why?

See the answer two answers up. It's the same issue.

This might not be the meaning of "ahead" you were expecting. With `patch-ahead`, you must specify the distance ahead that you want to look. If you want to know the next patch a turtle would cross into if it moved forward continuously, it is possible to find that out. See Next Patch Example, in the Code Examples section of the Models Library.

How do I give my turtles "vision"?

You can use `in-radius` to let a turtle see a circular area around it.

Several primitives let the turtle "look" at specific points. The `patch-ahead` primitive is useful for letting a turtle see what is directly in front of it. If you want the turtle to look in another direction besides straight ahead, try `patch-left-and-ahead` and `patch-right-and-ahead`.

If you want the turtle to have a full "cone" of vision, use the `in-cone` primitive.

You can also find out the next patch a turtle would cross into if it moved forward continuously. See Next Patch Example, in the Code Examples section of the Models Library.

Can agents sense what's in the drawing layer?

No. If you want to make marks that agents can sense, use patch colors.

I'm getting numbers like 0.10000000004 and 0.799999999999 instead of 0.1 and 0.8. Why?

See the "Math" section of the Programming Guide in the User Manual for a discussion of this issue.

The documentation says that `random-float 1` might return 0 but will never return 1. What if I want 1 to be included?

It really doesn't matter. Even if 1 were a possible result, it would only come up approximately 1 in 2^64 tries, which means you'd be waiting hundreds of years before it ever came up exactly 1.

Nonetheless, if you are convinced that it really must be possible to get 1, you can use `precision` to round your answer to a certain number of decimal places. For example:

```
print precision (random-float 1) 10
0.2745173723
```

(If you use this method, note that 0 and 1 are only half as likely to come up as other answers. To see why this is so, consider the case where you only keep one digit after the decimal point. Results between 0 and 0.5 get rounded to 0, but results between 0.5 and 1.5 get rounded to 1; the latter range is twice as large. If you want 0, 0.1, 0.2, ..., 0.9, and 1 to all be equally likely, an alternative is to write `random 11 / 10`; this gives all 11 answers with equal probability.)

How can I keep two turtles from occupying the same patch?

See One Turtle Per Patch Example, in the Code Examples section of the Models Library.

How can I find out if a turtle is dead?

When a turtle dies, it turns into `nobody`. `nobody` is a special value used in NetLogo used to indicate the absence of a turtle or patch. So for example:

```
if turtle 0 != nobody [ ... ]
```

You could also use `is-turtle?`:

```
if is-turtle? turtle 0 [ ... ]
```

Does NetLogo have arrays?

In the current version of NetLogo, lists are true linked lists, rather than having an array-based underlying implementation as in earlier NetLogo versions.

True arrays are available by using the array extension. See the Arrays & Tables section of the User Manual.

Does NetLogo have hash tables or associative arrays?

Yes, using the table extension. See the Arrays & Tables section of the User Manual.

How can I use different patch "neighborhoods" (circular, Von Neumann, Moore, etc.)?

The `in-radius` primitives lets you access circular neighborhoods of any radius.

The `neighbors` primitive gives you a Moore neighborhood of radius 1, and the `neighbors4` primitive gives you a Von Neumann neighborhood of radius 1.

For Moore or Von Neumann neighborhoods of a larger radius, see Moore & Von Neumann Example in the Code Examples section of the Models Library.

How can I convert an agentset to a list of agents, or vice versa?

If you want the list in a particular order, use the `sort` or `sort-by` primitives. The Lists section of the Programming Guide explains how to do this. See also Ask Ordering Example, in the Code Examples section of the Models Library.

If you want the list in a random order, here's how:

```
[self] of <agentset>
```

Because all operations on agentsets are in random order, the resulting list is in random order.

To convert a list of agents to an agentset, use the `turtle-set`, `patch-set`, or `link-set` primitives.

How do I stop foreach?

To stop a foreach from executing you need to define a separate procedure that contains only the foreach, for example:

```
to test
  foreach [1 2 3] [
    if ? = 2 [ stop ]
    print ?
  ]
end
```

This code will only print the number 1. The `stop` returns from the current procedure so nothing after the foreach will be executed either. (If the procedure is a reporter procedure, use `report` instead of `stop`.)

BehaviorSpace

How do I measure runs every n ticks?

Use `repeat` in your experiment's go commands, e.g.:

```
repeat 100 [ go ]
```

to measure the run after every 100 model steps. Essentially you are making one experiment step equal 100 model steps.

I'm varying a global variable I declared in the Procedures tab, but it doesn't work. Why?

It's probably because your setup commands or setup procedure are using `clear-all`, causing the values set by BehaviorSpace to be cleared.

One possible workaround is to change your experiment's setup commands to preserve the value of the variable, e.g.:

```
let old-var1 var1
setup
set var1 old-var1
```

This works because even `clear-all` doesn't clear the values of local variables made with `let`

Another possible workaround is to change your model's setup procedure to use more specific clearing commands to clear only what you want cleared.

Why are some of my results cut off in Excel?

In some versions of Excel, spreadsheets can't have more than 256 columns. (See a Microsoft support article on the subject.)

Possible workarounds include:

- Use a newer version of Excel, such as Excel 2007.
- Use a different program besides Excel.
- Ask BehaviorSpace to generate results in table format instead of, or in addition to, spreadsheet format. (Excel can read our table format, too.)
- Change your experiment so the result has fewer columns.

Extensions

I'm writing an extension. Why does the compiler say it can't find org.nlogo.api?

You need to add NetLogo.jar to your classpath when compiling. NetLogo.jar is included with NetLogo.

NetLogo Dictionary

Alphabetical: **A B C D E F G H I J L M N O P R S T U V W X Y ?**

Categories: Turtle − Patch − Agentset − Color − Control/Logic − World − Perspective
Input/Output − Files − List − String − Math − Plotting − Links − Movie − System − HubNet

Special: Variables − Keywords − Constants

p { margin−left: 1.5em ; } h3 { font−size: 115% ; } h4 { font−size: 100% ; margin−left: 1.5em ; background: white ; }

Categories

This is an approximate grouping. Remember that a turtle−related primitive might still be used by patches or the observer, and vice versa. To see which agents (turtles, patches, links, observer) can actually run a primitive, consult its dictionary entry.

Turtle−related

back (bk) *<breeds>*−at *<breeds>*−here *<breeds>*−on can−move? clear−turtles (ct) create−*<breeds>* create−ordered−*<breeds>* create−ordered−turtles (cro) create−turtles (crt) die distance distancexy downhill downhill4 dx dy face facexy forward (fd) hatch hatch−*<breeds>* hide−turtle (ht) home inspect is−*<breed>*? is−turtle? jump left (lt) move−to myself nobody no−turtles of other patch−ahead patch−at patch−at−heading−and−distance patch−here patch−left−and−ahead patch−right−and−ahead pen−down (pd) pen−erase (pe) pen−up (pu) random−xcor random−ycor right (rt) self set−default−shape __set−line−thickness setxy shapes show−turtle (st) sprout sprout−*<breeds>* stamp stamp−erase subject subtract−headings tie towards towardsxy turtle turtle−set turtles turtles−at turtles−here turtles−on turtles−own untie uphill uphill4

Patch−related

clear−patches (cp) diffuse diffuse4 distance distancexy import−pcolors import−pcolors−rgb inspect is−patch? myself neighbors neighbors4 nobody no−patches of other patch patch−at patch−ahead patch−at−heading−and−distance patch−here patch−left−and−ahead patch−right−and−ahead patch−set patches patches−own random−pxcor random−pycor self sprout sprout−*<breeds>* subject

---

Agentset

all? any? ask ask−concurrent at−points *<breeds>*−at *<breeds>*−here *<breeds>*−on count in−cone in−radius is−agent? is−agentset? is−patch−set? is−turtle−set? link−heading link−length link−set max−one−of min−one−of n−of neighbors neighbors4 no−patches no−turtles of one−of other patch−set patches sort sort−by turtle−set turtles with with−max with−min turtles−at turtles−here turtles−on

---

Color

approximate−hsb approximate−rgb base−colors color extract−hsb extract−rgb hsb import−pcolors import−pcolors−rgb pcolor rgb scale−color shade−of? wrap−color

---

Control flow and logic

and ask ask−concurrent carefully end error−message foreach if ifelse ifelse−value let loop map not or repeat report run runresult ; (semicolon) set stop startup to to−report wait while with−local−randomness without−interruption xor

World

clear−all (ca) clear−drawing (cd) clear−patches (cp) clear−turtles (ct) display import−drawing import−pcolors import−pcolors−rgb no−display max−pxcor max−pycor min−pxcor min−pycor reset−ticks tick tick−advance ticks world−width world−height

Perspective

follow follow−me reset−perspective (rp) ride ride−me subject watch watch−me

HubNet

hubnet−broadcast hubnet−broadcast−view hubnet−enter−message? hubnet−exit−message? hubnet−fetch−message hubnet−message hubnet−message−source hubnet−message−tag hubnet−message−waiting? hubnet−reset hubnet−send hubnet−send−view hubnet−set−client−interface

Input/output

beep clear−output date−and−time export−view export−interface export−output export−plot export−all−plots export−world import−drawing import−pcolors import−pcolors−rgb import−world mouse−down? mouse−inside? mouse−patch mouse−xcor mouse−ycor output−print output−show output−type output−write print read−from−string reset−timer set−current−directory show timer type user−directory user−file user−new−file user−input user−message user−one−of user−yes−or−no? write

File

file−at−end? file−close file−close−all file−delete file−exists? file−flush file−open file−print file−read file−read−characters file−read−line file−show file−type file−write user−directory user−file user−new−file

List

but−first but−last empty? filter first foreach fput histogram is−list? item last length list lput map member? modes n−of n−values of position one−of reduce remove remove−duplicates remove−item replace−item reverse sentence shuffle sort sort−by sublist

String

Operators (<, >, =, !=, <=, >=) but−first but−last empty? first is−string? item last length member? position remove remove−item read−from−string replace−item reverse substring word

Mathematical

Arithmetic Operators (+, *, −, /, ^, <, >, =, !=, <=, >=) abs acos asin atan ceiling cos e exp floor int ln log max mean median min mod modes new−seed pi precision random random−exponential random−float random−gamma random−normal random−poisson random−seed remainder round sin sqrt standard−deviation subtract−headings sum tan variance

Plotting

autoplot? auto−plot−off auto−plot−on clear−all−plots clear−plot create−temporary−plot−pen export−plot export−all−plots histogram plot plot−name plot−pen−exists? plot−pen−down plot−pen−reset plot−pen−up plot−x−max plot−x−min plot−y−max plot−y−min plotxy set−current−plot set−current−plot−pen set−histogram−num−bars set−plot−pen−color set−plot−pen−interval set−plot−pen−mode set−plot−x−range set−plot−y−range

Links

both−ends clear−links create−<breed>−from create−<breeds>−from create−<breed>−to create−<breeds>−to create−<breed>−with create−<breeds>−with create−link−from create−links−from create−link−to create−links−to create−link−with create−links−with in−<breed>−neighbor? in−<breed>−neighbors in−<breed>−from in−link−neighbor? in−link−neighbors in−link−from is−directed−link? is−link? is−undirected−link? layout−circle __layout−magspring layout−radial layout−spring layout−tutte <breed>−neighbor? <breed>−neighbors <breed>−with link−neighbor? link links links−own <link−breeds>−own link−neighbors link−with my−<breeds> my−in−<breeds> my−in−links my−links my−out−<breeds> my−out−links no−links other−end out−<breed>−neighbor? out−<breed>−neighbors out−<breed>−to out−link−neighbor? out−link−neighbors out−link−to tie

Movie

movie−cancel movie−close movie−grab−view movie−grab−interface movie−set−frame−rate movie−start movie−status

System

netlogo−applet? netlogo−version

Built−In Variables

Turtles

breed color heading hidden? label label−color pen−mode pen−size shape size who xcor ycor

Patches

pcolor plabel plabel−color pxcor pycor

Links

breed color end1 end2 hidden? label label−color shape thickness tie−mode

Other

?

Keywords

breed directed−link−breed end globals __includes patches−own to to−report turtles−own undirected−link−breed

Constants

Mathematical Constants

e = 2.718281828459045
pi = 3.141592653589793

Boolean Constants

false
true

Color Constants

black = 0
gray = 5
white = 9.9
red = 15
orange = 25
brown = 35
yellow = 45
green = 55
lime = 65
turquoise = 75
cyan = 85
sky = 95

blue = 105
violet = 115
magenta = 125
pink = 135

See the Colors section of the Programming Guide for more details.

A

abs

abs *number*

Reports the absolute value of *number*.

```
show abs −7
=> 7
show abs 5
=> 5
```

acos

acos *number*

Reports the arc cosine (inverse cosine) of the given number. The input must be in the range −1 to 1. The result is in degrees, and lies in the range 0 to 180.

all?

all? *agentset* [*reporter*]

Reports true if all of the agents in the agentset report true for the given reporter. Otherwise false.

The reporter must report a boolean value for every agent (either true or false), otherwise an error occurs.

```
if all? turtles [color = red]
  [ show "every turtle is red!" ]
```

See also any?.

and

condition1* and *condition2

Reports true if both *condition1* and *condition2* are true.

Note that if *condition1* is false, then *condition2* will not be run (since it can't affect the result).

```
if (pxcor > 0) and (pycor > 0)
```

```
  [ set pcolor blue ]  ;; the upper-right quadrant of
                       ;; patches turn blue
```

any?

any? *agentset*

Reports true if the given agentset is non−empty, false otherwise.

Equivalent to "count *agentset* > 0", but more efficient (and arguably more readable).

```
if any? turtles with [color = red]
  [ show "at least one turtle is red!" ]
```

Note: nobody is not an agentset. You only get nobody back in situations where you were expecting a single agent, not a whole agentset. If any? gets nobody as input, an error results.

See also all, nobody.

approximate−hsb

approximate−hsb *hue saturation brightness*

Reports a number in the range 0 to 140, not including 140 itself, that represents the given color, specified in the HSB spectrum, in NetLogo's color space.

All three values should be in the range 0 to 255.

The color reported may be only an approximation, since the NetLogo color space does not include all possible colors. (It contains only certain discrete hues, and for each hue, either saturation or brightness may vary, but not both −− at least one of the two is always 255.)

```
show approximate-hsb 0 0 0
=> 0  ;; (black)
show approximate-hsb 0.5 1.0 1.0
=> 85 ;; (cyan)
```

See also extract−hsb, approximate−rgb, extract−rgb.

approximate−rgb

approximate−rgb *red green blue*

Reports a number in the range 0 to 140, not including 140 itself, that represents the given color, specified in the RGB spectrum, in NetLogo's color space.

All three inputs should be in the range 0 to 255.

The color reported may be only an approximation, since the NetLogo color space does not include all possible colors. (See approximate−hsb for a description of what parts of the HSB color space NetLogo colors cover; this is difficult to characterize in RGB terms.)

```
show approximate-rgb 0 0 0
=> 0  ;; black
show approximate-rgb 0 1 1
=> 85 ;; cyan
```

See also extract−rgb, approximate−hsb, and extract−hsb.

Arithmetic Operators (+, *, −, /, ^, <, >, =, !=, <=, >=)

All of these operators take two inputs, and all act as "infix operators" (going between the two inputs, as in standard mathematical use). NetLogo correctly supports order of operations for infix operators.

The operators work as follows: + is addition, * is multiplication, − is subtraction, / is division, ^ is exponentiation, < is less than, > is greater than, = is equal to, != is not equal to, <= is less than or equal, >= is greater than or equal.

Note that the subtraction operator (−) always takes two inputs unless you put parentheses around it, in which case it can take one input. For example, to take the negative of x, write (− x), with the parentheses.

All of the comparison operators also work on strings.

All of the comparison operators work on agents. Turtles are compared by who number. Patches are compared top to bottom left to right, so patch 0 10 is less than patch 0 9 and patch 9 0 is less than patch 10 0. Links are ordered by end points and in case of a tie by breed. So link 0 9 is before link 1 10 as the end1 is smaller, and link 0 8 is less than link 0 9. If there are multiple breeds of links unbreeded links will come before breeded links of the same end points and breeded links will be sorted in the order they are declared in the Procedures tab.

Agentsets can be tested for equality or inequality. Two agentsets are equal if they are the same type (turtle or patch) and contain the same agents.

If you are not sure how NetLogo will interpret your code, you should add parentheses.

```
show 5 * 6 + 6 / 3
=> 32
show 5 * (6 + 6) / 3
=> 20
```

asin

asin *number*

Reports the arc sine (inverse sine) of the given number. The input must be in the range −1 to 1. The result is in degrees, and lies in the range −90 to 90.

ask

ask *agentset* [*commands*]
ask *agent* [*commands*]

The specified agent or agentset runs the given commands.

```
ask turtles [ fd 1 ]
  ;; all turtles move forward one step
ask patches [ set pcolor red ]
  ;; all patches turn red
ask turtle 4 [ rt 90 ]
  ;; only the turtle with id 4 turns right
```

Note: only the observer can ask all turtles or all patches. This prevents you from inadvertently having all turtles ask all turtles or all patches ask all patches, which is a common mistake to make if you're not careful about which agents will run the code you are writing.

Note: Only the agents that are in the agentset *at the time the ask begins* run the commands.

---

ask−concurrent

ask−concurrent *agentset* [*commands*]

The agents in the given agentset run the given commands, using a turn−taking mechanism to produce simulated concurrency. See the Ask−Concurrent section of the Programming Guide for details on how this works.

Note: Only the agents that are in the agentset *at the time the ask begins* run the commands.

See also without−interruption.

---

at−points

***agentset* at−points [[*x1 y1*] [*x2 y2*] ...]**

Reports a subset of the given agentset that includes only the agents on the patches the given distances away from the calling agent. The distances are specified as a list of two−item lists, where the two items are the x and y offsets.

If the caller is the observer, then the points are measured relative to the origin, in other words, the points are taken as absolute patch coordinates.

If the caller is a turtle, the points are measured relative to the turtle's exact location, and not from the center of the patch under the turtle.

```
ask turtles at−points [[2 4] [1 2] [10 15]]
  [ fd 1 ]  ;; only the turtles on the patches at the
            ;; distances (2,4), (1,2) and (10,15),
            ;; relative to the caller, move
```

---

atan

atan *x y*

Reports the arc tangent, in degrees (from 0 to 360), of x divided by y.

When y is 0: if x is positive, it reports 90; if x is negative, it reports 270; if x is zero, you get an error.

Note that this version of atan is designed to conform to the geometry of the NetLogo world, where a heading of 0 is straight up, 90 is to the right, and so on clockwise around the circle. (Normally in geometry an angle of 0 is right, 90 is up, and so on, counterclockwise around the circle, and atan would be defined accordingly.)

```
show atan 1 −1
=> 135
show atan −1 1
=> 315
```

---

autoplot?

autoplot?

Reports true if auto−plotting is on for the current plot, false otherwise.

---

auto−plot−off
auto−plot−on

auto−plot−off
auto−plot−on

This pair of commands is used to control the NetLogo feature of auto−plotting in the current plot. Auto−plotting will automatically update the x and y axes of the plot whenever the current pen exceeds these boundaries. It is useful when wanting to show all plotted values in the current plot, regardless of the current plot ranges.

B

---

back
bk

back *number*

The turtle moves backward by *number* steps. (If *number* is negative, the turtle moves forward.)

Turtles using this primitive can move a maximum of one unit per time increment. So `bk 0.5` and `bk 1` both take one unit of time, but `bk 3` takes three.

If the turtle cannot move backward *number* steps because it is not permitted by the current topology the turtle will complete as many steps of 1 as it can and stop.

See also forward, jump, can−move?.

base−colors

base−colors

Reports a list of the 14 basic NetLogo hues.

```
print base-colors
=> [5 15 25 35 45 55 65 75 85 95 105 115 125 135]
ask turtles [ set color one-of base-colors ]
;; each turtle turns a random base color
ask turtles [ set color one-of remove gray base-colors ]
;; each turtle turns a random base color except for gray
```

beep

beep

Emits a beep. Note that the beep sounds immediately, so several beep commands in close succession may produce only one audible sound.

Example:

```
beep                        ;; emits one beep
repeat 3 [ beep ]           ;; emits 3 beeps at once,
                            ;; so you only hear one sound
repeat 3 [ beep wait 0.1 ] ;; produces 3 beeps in succession,
                            ;; separated by 1/10th of a second
```

both−ends

both−ends

Reports the agentset of the 2 nodes connected by this link.

```
crt 2
ask turtle 0 [ create-link-with turtle 1 ]
ask link 0 1 [
  ask both-ends [ set color red ] ;; turtles 0 and 1 both turn red
]
```

breed

breed

This is a built−in turtle and link variable. It holds the agentset of all turtles or links of the same breed as this turtle or link. (For turtles or links that do not have any particular breed, this is the turtles agentset of all turtles or the links agentset of all links respectively.) You can set this variable to change a turtle or link's breed.

See also breed, directed−link−breed, undirected−link−breed

Example:

```
breed [cats cat]
breed [dogs dog]
;; turtle code:
if breed = cats [ show "meow!" ]
set breed dogs
show "woof!"

directed−link−breed [ roads road ]
;; link code
if breed = roads [ set color gray ]
```

---

breed

breed [<*breeds*> <*breed*>]

This keyword, like the globals, turtles−own, and patches−own keywords, can only be used at the beginning of the Procedures tab, before any procedure definitions. It defines a breed. The first input defines the name of the agentset associated with the breed. The second input defines the name of a single member of the breed.

Any turtle of the given breed:

- is part of the agentset named by the breed name
- has its breed built−in variable set to that agentset

Most often, the agentset is used in conjunction with ask to give commands to only the turtles of a particular breed.

```
breed [mice mouse]
breed [frogs frog]
to setup
  clear−all
  create−mice 50
  ask mice [ set color white ]
  create−frogs 50
  ask frogs [ set color green ]
  show [breed] of one−of mice    ;; prints mice
  show [breed] of one−of frogs   ;; prints frogs
end

show mouse 1
;; prints (mouse 1)
show frog 51
;; prints (frog 51)
show turtle 51
;; prints (frog 51)
```

See also globals, patches−own, turtles−own, <*breeds*>−own, create−<*breeds*>, <*breeds*>−at, <*breeds*>−here.

but−first
bf
but−last
bl

but−first *list*
but−first *string*
but−last *list*
but−last *string*

When used on a list, but−first reports all of the list items of *list* except the first, and but−last reports all of the list items of *list* except the last.

On strings, but−first and but−last report a shorter string omitting the first or last character of the original string.

```
;; mylist is [2 4 6 5 8 12]
set mylist but−first mylist
;; mylist is now [4 6 5 8 12]
set mylist but−last mylist
;; mylist is now [4 6 5 8]
show but−first "string"
;; prints "tring"
show but−last "string"
;; prints "strin"
```

C

can−move?

can−move? *distance*

Reports true if the calling turtle can move *distance* in the direction it is facing without violating the topology; reports false otherwise.

It is equivalent to:

```
patch−ahead distance != nobody
```

carefully

carefully [*commands1*] [*commands2*]

Runs *commands1*. If a runtime error occurs inside *commands1*, NetLogo won't stop and alert the user that an error occurred. It will suppress the error and run *commands2* instead.

The error−message reporter can be used in *commands2* to find out what error was suppressed in *commands1*. See error−message.

Note: both sets of commands run without interruption (as with the without−interruption command).

```
carefully [ show 1 / 1 ] [ print error−message ]
=> 1
carefully [ show 1 / 0 ] [ print error−message ]
=> division by zero
```

---

ceiling

ceiling *number*

Reports the smallest integer greater than or equal to *number*.

```
show ceiling 4.5
=> 5
show ceiling −4.5
=> −4
```

---

clear−all
ca

clear−all

Resets all global variables to zero, and calls reset−ticks, clear−turtles, clear−patches, clear−drawing, clear−all−plots, and clear−output.

---

clear−all−plots

clear−all−plots

Clears every plot in the model. See clear−plot for more information.

---

clear−drawing
cd

clear−drawing

Clears all lines and stamps drawn by turtles.

---

clear−links

clear−links

Kills all links.

See also die.

---

clear−output

clear−output

Clears all text from the model's output area, if it has one. Otherwise does nothing.

---

clear−patches
cp

clear−patches

Clears the patches by resetting all patch variables to their default initial values, including setting their color to black.

---

clear−plot

clear−plot

In the current plot only, resets all plot pens, deletes all temporary plot pens, resets the plot to its default values (for x range, y range, etc.), and resets all permanent plot pens to their default values. The default values for the plot and for the permanent plot pens are set in the plot Edit dialog, which is displayed when you edit the plot. If there are no plot pens after deleting all temporary pens, that is to say if there are no permanent plot pens, a default plot pen will be created with the following initial settings:

- Pen: down
- Color: black
- Mode: 0 (line mode)
- Name: "default"
- Interval: 1

See also clear−all−plots.

---

clear−turtles
ct

clear−turtles

Kills all turtles.

Also resets the who numbering, so the next turtle created will be turtle 0.

See also die.

---

color

color

This is a built−in turtle or link variable. It holds the color of the turtle or link. You can set this variable to make the turtle or link change color.

See also pcolor.

---

cos

cos *number*

Reports the cosine of the given angle. Assumes the angle is given in degrees.

```
show cos 180
=> −1
```

---

count

count *agentset*

Reports the number of agents in the given agentset.

```
show count turtles
;; prints the total number of turtles
show count patches with [pcolor = red]
;; prints the total number of red patches
```

---

create−ordered−turtles
cro
create−ordered−<*breeds*>

create−ordered−turtles *number*
create−ordered−turtles *number* [*commands*]
create−ordered<*breeds*> *number*
create−ordered<*breeds*> *number* [*commands*]

Creates *number* new turtles. New turtles start at position (0, 0), are created with the 14 primary colors, and have headings from 0 to 360, evenly spaced.

If the create−ordered−<*breeds*> form is used, the new turtles are created as members of the given breed.

If *commands* are supplied, the new turtles immediately run them *commands*. This is useful for giving the new turtles a different color, heading, or whatever. (The new turtles are created all at once then run one at a time, in random order.)

```
cro 100 [ fd 10 ]  ;; makes an evenly spaced circle
```

Note: While the commands are running, no other agents are allowed to run any code (as with the `without−interruption` command). This ensures that if `ask−concurrent` is being used, the new turtles cannot interact with any other agents until they are fully initialized.

---

create−<breed>−to
create−<breed>−from
create−<breed>−with
create−link−to
create−link−from
create−link−with

create−<breed>−to *turtle*
create−<breed>−to *turtle* [*commands*]
create−<breed>−from *turtle*
create−<breed>−from *turtle* [*commands*]
create−<breed>−with *turtle*
create−<breed>−with *turtle* [*commands*]
create−<breeds>−to *turtleset*
create−<breeds>−to *turtleset* [*commands*]
create−<breeds>−from *turtleset*
create−<breeds>−from *turtleset* [*commands*]
create−<breeds>−with *turtleset*
create−<breeds>−with *turtleset* [*commands*]
create−link−to *turtle*
create−link−to *turtle* [*commands*]
create−link−from *turtle*
create−link−from *turtle* [*commands*]
create−link−with *turtle*
create−link−with *turtle* [*commands*]
create−links−to *turtleset*
create−links−to *turtleset* [*commands*]
create−links−from *turtleset*
create−links−from *turtleset* [*commands*]
create−links−with *turtleset*
create−links−with *turtleset* [*commands*]

Used for creating breeded and unbreeded links between turtles.

create−link−with creates an undirected link between the caller and *agent*. create−link−to creates a directed link from the caller to *agent*. create−link−from creates a directed link from *agent* to the caller.

When the plural form of the breed name is used, an *agentset* is expected instead of an agent and links are created between the caller and all agents in the agentset.

The optional command block is the set of commands each newly formed link runs. (The links are created all at once then run one at a time, in random order.)

A node cannot be linked to itself. Also, you cannot have more than one undirected link of the same breed between the same two nodes, nor can you have more than one directed link of the same breed going in the same direction between two nodes.

If you try to create a link where one (of the same breed) already exists, nothing happens. If you try to create a link from a turtle to itself you get a runtime error.

```
to setup
   crt 5
   ;; turtle 1 creates links with all other turtles
   ;; the link between the turtle and itself is ignored
   ask turtle 0 [ create−links−with other turtles ]
   show count links ;; shows 4
   ;; this does nothing since the link already exists
   ask turtle 0 [ create−link−with turtle 1 ]
   show count links ;; shows 4 since the previous link already existed
   ask turtle 2 [ create−link−with turtle 1 ]
   show count links ;; shows 5
end

directed−link−breed [red−links red−link]
undirected−link−breed [blue−links blue−link]

to setup
  crt 5
  ;; create links in both directions between turtle 0
  ;; and all other turtles
  ask turtle 0 [ create−red−links−to turtles ]
  ask turtle 0 [ create−red−links−from turtles ]
  show count links ;; shows 8
  ;; now create undirected links between turtle 0 and other turtles
  ask turtle 0 [ create−blue−links−with turtles ]
  show count links ;; shows 12
end
```

---

create−turtles
crt
create−<*breeds*>

create−turtles *number*
create−turtles *number* [*commands*]
create−<*breeds*> *number*
create−<*breeds*> *number* [*commands*]

Creates *number* new turtles . New turtles have random headings and the color is randomly selected from the 14 primary colors.

If the create−<*breeds*> form is used, the new turtles are created as members of the given breed.

If *commands* are supplied, the new turtles immediately run them *commands*. This is useful for giving the new turtles a different color, heading, or whatever. (The new turtles are created all at once then run one at a time, in random order.)

```
crt 100 [ fd 10 ]     ;; makes a circle

breed [canaries canary]
breed [snakes snake]
to setup
  clear−all
  create−canaries 50 [ set color yellow ]
  create−snakes 50 [ set color green ]
end
```

Note: While the commands are running, no other agents are allowed to run any code (as with the `without−interruption` command). This ensures that if `ask−concurrent` is being used, the new turtles cannot interact with any other agents until they are fully initialized.

See also hatch, sprout.

---

create−temporary−plot−pen

create−temporary−plot−pen *string*

A new temporary plot pen with the given name is created in the current plot and set to be the current pen.

Few models will want to use this primitive, because all temporary pens disappear when clear−plot or clear−all−plots are called. The normal way to make a pen is to make a permanent pen in the plot's Edit dialog.

If a temporary pen with that name already exists in the current plot, no new pen is created, and the existing pen is set to the the current pen. If a permanent pen with that name already exists in the current plot, you get a runtime error.

The new temporary plot pen has the following initial settings:

- Pen: down
- Color: black
- Mode: 0 (line mode)
- Interval: 1

See: clear−plot, clear−all−plots, and set−current−plot−pen.

D

date−and−time

date−and−time

Reports a string containing the current date and time. The format is shown below. All fields are fixed width, so they are always at the same locations in the string. The potential resolution of the clock is milliseconds. (Whether you get resolution that high in practice may vary from system to system, depending on the capabilities of the underlying Java Virtual Machine.)

```
show date−and−time
=> "01:19:36.685 PM 19−Sep−2002"
```

die

die

The turtle dies.

```
if xcor > 20 [ die ]


;; all turtles with xcor greater than 20 die
```

See also: ct

diffuse

diffuse *patch−variable number*

Tells each patch to share (*number* * 100) percent of the value of *patch−variable* with its eight neighboring patches. *number* should be between 0 and 1. Regardless of topology the sum of *patch−variable* will be conserved across the world. If a patch has fewer than eight neighbors the remainder stays on the patch at the edge of the world.

Note that this is an observer command only, even though you might expect it to be a patch command. (The reason is that it acts on all the patches at once −− patch commands act on individual patches.)

```
diffuse chemical 0.5
;; each patch diffuses 50% of its variable
;; chemical to its neighboring 8 patches. Thus,
;; each patch gets 1/8 of 50% of the chemical
;; from each neighboring patch.)
```

diffuse4

diffuse4 *patch−variable number*

Like diffuse, but only diffuses to the four neighboring patches (to the north, south, east, and west), not to the diagonal neighbors.

```
diffuse4 chemical 0.5
;; each patch diffuses 50% of its variable
;; chemical to its neighboring 4 patches. Thus,
;; each patch gets 1/4 of 50% of the chemical
;; from each neighboring patch.)
```

---

directed−link−breed

directed−link−breed [*<link−breeds>* *<link−breed>*]

This keyword, like the globals and breeds keywords, can only be used at the beginning of the Procedures tab, before any procedure definitions. It defines a directed link breed. Links of a particular breed are always all directed or all undirected The first input defines the name of the agentset associated with the link breed. The second input defines the name of a single member of the breed. Directed links can be created using create−link(s)−to, and create−link(s)−from, but not `create−link(s)−with`

Any link of the given link breed:

- is part of the agentset named by the link breed name
- has its built−in variable `breed` set to that agentset
- is directed or undirected as declared by the keyword

Most often, the agentset is used in conjunction with ask to give commands to only the links of a particular breed.

```
directed−link−breed [streets street]
directed−link−breed [highways highway]
to setup
  clear−all
  crt 2
  ;; create a link from turtle 0 to turtle 1
  ask turtle 0 [ create−street−to turtle 1 ]
  ;; create a link from turtle 1 to turtle 0
  ask turtle 0 [ create−highway−from turtle 1 ]
end

ask turtle 0 [ show one−of in−links ]
;; prints (street 0 1)
ask turtle 0 [ show one−of out−links ]
;; prints (highway 1 0)
```

See also breed, undirected−link−breed

---

display

display

Causes the view to be updated immediately. (Exception: if the user is using the speed slider to fast−forward the model, then the update may be skipped.)

Also undoes the effect of the no−display command, so that if view updates were suspended by that command, they will resume.

```
no−display
ask turtles [ jump 10 set color blue set size 5 ]
display
;; turtles move, change color, and grow, with none of
;; their intermediate states visible to the user, only
;; their final state
```

Even if no−display was not used, "display" can still be useful, because ordinarily NetLogo is free to skip some view updates, so that fewer total updates take place, so that models run faster. This command lets you force a view update, so whatever changes have taken place in the world are visible to the user.

```
ask turtles [ set color red ]
display
ask turtles [ set color blue]
;; turtles turn red, then blue; use of "display" forces
;; red turtles to appear briefly
```

Note that display and no−display operate independently of the switch in the view control strip that freezes the view.

See also no−display.

---

distance

distance *agent*

Reports the distance from this agent to the given turtle or patch.

The distance to or a from a patch is measured from the center of the patch. Turtles and patches use the wrapped distance (around the edges of the world) if wrapping is allowed by the topology and the wrapped distance is shorter.

```
ask turtles [ show max−one−of turtles [distance myself] ]
;; each turtle prints the turtle farthest from itself
```

---

distancexy

distancexy ***xcor ycor***

Reports the distance from this agent to the point (*xcor*, *ycor*).

The distance from a patch is measured from the center of the patch. Turtles and patches use the wrapped distance (around the edges of the world) if wrapping is allowed by the topology and the wrapped distance is shorter.

```
if (distancexy 0 0) > 10
  [ set color green ]
;; all turtles more than 10 units from
;; the center of the world turn green.
```

---

downhill
downhill4

downhill ***patch−variable***
downhill4 ***patch−variable***

Moves the turtle to the neighboring patch with the lowest value for *patch−variable*. If no neighboring patch has a smaller value than the current patch, the turtle stays put. If there are multiple patches with the same lowest value, the turtle picks one randomly. Non−numeric values are ignored.

downhill considers the eight neighboring patches; downhill4 only considers the four neighbors.

Equivalent to the following code (assumes variable values are numeric):

```
move−to patch−here  ;; go to patch center
let p min−one−of neighbors [patch−variable]  ;; or neighbors4
if [patch−variable] of p < patch−variable [
  face p
  move−to p
]
```

Note that the turtle always ends up on a patch center and has a heading that is a multiple of 45 (downhill) or 90 (downhill4).

See also uphill, uphill4.

---

dx
dy

dx
dy

Reports the x−increment or y−increment (the amount by which the turtle's xcor or ycor would change) if the turtle were to take one step forward in its current heading.

Note: dx is simply the sine of the turtle's heading, and dy is simply the cosine. (If this is the reverse of what you expected, it's because in NetLogo a heading of 0 is north and 90 is east, which is the reverse of how angles are usually defined in geometry.)

Note: In earlier versions of NetLogo, these primitives were used in many situations where the new `patch-ahead` primitive is now more appropriate.

E

empty?

empty? ***list***
empty? ***string***

Reports true if the given list or string is empty, false otherwise.

Note: the empty list is written `[]`. The empty string is written `""`.

end

end

Used to conclude a procedure. See to and to-report.

end1

end1

This is a built-in link variable. It indicates the first endpoint (turtle) of a link. For directed links this will always be the source for undirected links it will always be the turtle with the lower who number. You cannot set end1.

```
crt 2
ask turtle 0
[ create-link-to turtle 1 ]
ask links
[ show end1 ] ;; shows turtle 0
```

end2

end2

This is a built-in link variable. It indicates the second endpoint (turtle) of a link. For directed links this will always be the destination for undirected links it will always be the turtle with the higher who number. You cannot set end2.

```
crt 2
ask turtle 1
```

```
[ create-link-with turtle 0 ]
ask links
[ show end2 ] ;; shows turtle 1
```

error-message

error-message

Reports a string describing the error that was suppressed by carefully.

This reporter can only be used in the second block of a carefully command.

See also carefully.

every

every *number* [*commands*]

Runs the given commands only if it's been more than *number* seconds since the last time this agent ran them in this context. Otherwise, the commands are skipped.

By itself, every doesn't make commands run over and over again. You need to use every inside a loop, or inside a forever button, if you want the commands run over and over again. every only limits how often the commands run.

Above, "in this context" means during the same ask (or button press or command typed in the Command Center). So it doesn't make sense to write `ask turtles [ every 0.5 [ ... ] ]`, because when the ask finishes the turtles will all discard their timers for the "every". The correct usage is shown below.

```
every 0.5 [ ask turtles [ fd 1 ] ]
;; twice a second the turtles will move forward 1
every 2 [ set index index + 1 ]
;; every 2 seconds index is incremented
```

See also wait.

exp

exp *number*

Reports the value of e raised to the *number* power.

Note: This is the same as e ^ *number*.

export-view
export-interface
export-output
export-plot

export−all−plots
export−world

export−view *filename*
export−interface *filename*
export−output *filename*
export−plot *plotname filename*
export−all−plots *filename*
export−world *filename*

export−view writes the current contents of the current view to an external file given by the string *filename*. The file is saved in PNG (Portable Network Graphics) format, so it is recommended to supply a filename ending in ".png".

export−interface is similar, but for the whole interface tab.

export−output writes the contents of the model's output area to an external file given by the string *filename*. (If the model does not have a separate output area, the output portion of the Command Center is used.)

export−plot writes the x and y values of all points plotted by all the plot pens in the plot given by the string *plotname* to an external file given by the string *filename*. If a pen is in bar mode (mode 0) and the y value of the point plotted is greater than 0, the upper−left corner point of the bar will be exported. If the y value is less than 0, then the lower−left corner point of the bar will be exported.

export−all−plots writes every plot in the current model to an external file given by the string *filename*. Each plot is identical in format to the output of export−plot.

export−world writes the values of all variables, both built−in and user−defined, including all observer, turtle, and patch variables, the drawing, the contents of the output area if one exists, the contents of any plots and the state of the random number generator, to an external file given by the string *filename*. (The result file can be read back into NetLogo with the import−world primitive.) export−world does not save the state of open files.

export−plot, export−all−plots and export−world save files in in plain−text, "comma−separated values" (`.csv`) format. CSV files can be read by most popular spreadsheet and database programs as well as any text editor.

If the file already exists, it is overwritten.

If you wish to export to a file in a location other than the model's location, you should include the full path to the file you wish to export. (Use the forward−slash "/" as the folder separator.)

Note that the functionality of these primitives is also available directly from NetLogo's File menu.

```
export−world "fire.csv"
;; exports the state of the model to the file fire.csv
;; located in the NetLogo folder
export−plot "Temperature" "c:/My Documents/plot.csv"
;; exports the plot named
;; "Temperature" to the file plot.csv located in
;; the C:\My Documents folder
```

```
export-all-plots "c:/My Documents/plots.csv"
;; exports all plots to the file plots.csv
;; located in the C:\My Documents folder
```

extract-hsb

extract-hsb *color*

Reports a list of three values in the range 0 to 255 representing the hue, saturation and brightness, respectively, of the given NetLogo *color* in the range 0 to 140, not including 140 itself.

```
show extract-hsb red
=> [0.0090 0.809 0.843]
show extract-hsb cyan
=> [0.5 0.571 0.769]
```

See also approximate-hsb, approximate-rgb, extract-rgb.

extract-rgb

extract-rgb *color*

Reports a list of three values in the range 0 to 255 representing the levels of red, green, and blue, respectively, of the given NetLogo *color* in the range 0 to 140, not including 140 itself.

```
show extract-rgb red
=> [0.843 0.196 0.161]
show extract-rgb cyan
=> [0.329 0.769 0.769]
```

See also approximate-rgb, approximate-hsb, extract-hsb.

F

face

face *agent*

Set the caller's heading towards *agent*.

If wrapping is allowed by the topology and the wrapped distance (around the edges of the world) is shorter, face will use the wrapped path.

If the caller and the agent are at the exact same position, the caller's heading won't change.

facexy

facexy *number number*

Set the caller's heading towards the point (x,y).

If wrapping is allowed by the topology and the wrapped distance (around the edges of the world) is shorter and wrapping is allowed, facexy will use the wrapped path.

If the caller is on the point (x,y), the caller's heading won't change.

---

file−at−end?

file−at−end?

Reports true when there are no more characters left to read in from the current file (that was opened previously with file−open). Otherwise, reports false.

```
file−open "my−file.txt"
print file−at−end?
=> false ;; Can still read in more characters
print file−read−line
=> This is the last line in file
print file−at−end
=> true ;; We reached the end of the file
```

See also file−open, file−close−all.

---

file−close

file−close

Closes a file that has been opened previously with file−open.

Note that this and file−close−all are the only ways to restart to the beginning of an opened file or to switch between file modes.

If no file is open, does nothing.

See also file−close−all, file−open.

---

file−close−all

file−close−all

Closes all files (if any) that have been opened previously with file−open.

See also file−close, file−open.

---

file−delete

file−delete *string*

Deletes the file specified as *string*

string must be an existing file with writable permission by the user. Also, the file cannot be open. Use the command file−close to close an opened file before deletion.

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set−current−directory. It is defaulted to the model's directory.

---

file−exists?

file−exists? *string*

Reports true if *string* is the name of an existing file on the system. Otherwise it reports false.

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set−current−directory. It defaults to to the model's directory.

---

file−flush

file−flush

Forces file updates to be written to disk. When you use file−write or other output commands, the values may not be immediately written to disk. This improves the performance of the file output commands. Closing a file ensures that all output is written to disk.

Sometimes you need to ensure that data is written to disk without closing the file. For example, you could be using a file to communicate with another program on your machine and want the other program to be able to see the output immediately.

---

file−open

file−open *string*

This command will interpret *string* as a path name to a file and open the file. You may then use the reporters file−read, file−read−line, and file−read−characters to read in from the file, or file−write, file−print, file−type, or file−show to write out to the file.

Note that you can only open a file for reading or writing but not both. The next file i/o primitive you use after this command dictates which mode the file is opened in. To switch modes, you need to close the file using file−close.

Also, the file must already exist if opening a file in reading mode.

When opening a file in writing mode, all new data will be appended to the end of the original file. If there is no original file, a new blank file will be created in its place. (You must have write permission in the file's directory.) (If you don't want to append, but want to replace the file's existing contents, use file−delete to delete it first, perhaps inside a carefully if you're not sure whether it already exists.)

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set−current−directory. It is defaulted to the model's directory.

```
file−open "my−file−in.txt"
print file−read−line
=> First line in file ;; File is in reading mode
file−open "C:\\NetLogo\\my−file−out.txt"
;; assuming Windows machine
file−print "Hello World" ;; File is in writing mode
```

See also file−close.

---

file−print

file−print *value*

Prints *value* to an opened file, followed by a carriage return.

The calling agent is *not* printed before the value, unlike file−show.

Note that this command is the file i/o equivalent of print, and file−open needs to be called before this command can be used.

See also file−show, file−type, and file−write.

---

file−read

file−read

This reporter will read in the next constant from the opened file and interpret it as if it had been typed in the Command Center. It reports the resulting value. The result may be a number, list, string, boolean, or the special value nobody.

Whitespace separates the constants. Each call to file−read will skip past both leading and trailing whitespace.

Note that strings need to have quotes around them. Use the command file−write to have quotes included.

Also note that the file−open command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter file−at−end? to determine if you are at the end of the file.

```
file−open "my−file.data"
```

```
print file-read + 5
;; Next value is the number 1
=> 6
print length file-read
;; Next value is the list [1 2 3 4]
=> 4
```

See also file-open and file-write.

file-read-characters

file-read-characters *number*

Reports the given *number* of characters from an opened file as a string. If there are fewer than that many characters left, it will report all of the remaining characters.

Note that it will return every character including newlines and spaces.

Also note that the file-open command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter file-at-end? to determine if you are at the end of the file.

```
file-open "my-file.txt"
print file-read-characters 5
;; Current line in file is "Hello World"
=> Hello
```

See also file-open.

file-read-line

file-read-line

Reads the next line in the file and reports it as a string. It determines the end of the file by a carriage return, an end of file character or both in a row. It does not return the line terminator characters.

Also note that the file-open command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter file-at-end? to determine if you are at the end of the file.

```
file-open "my-file.txt"
print file-read-line
=> Hello World
```

See also file-open.

file-show

file-show *value*

Prints *value* to an opened file, preceded by the calling agent, and followed by a carriage return. (The calling agent is included to help you keep track of what agents are producing which lines of output.)

Also, all strings have their quotes included similar to file−write.

Note that this command is the file i/o equivalent of show, and file−open needs to be called before this command can be used.

See also file−print, file−type, and file−write.

---

file−type

file−type *value*

Prints *value* to an opened file, *not* followed by a carriage return (unlike file−print and file−show). The lack of a carriage return allows you to print several values on the same line.

The calling agent is *not* printed before the value. unlike file−show.

Note that this command is the file i/o equivalent of type, and file−open needs to be called before this command can be used.

See also file−print, file−show, and file−write.

---

file−write

file−write *value*

This command will output *value*, which can be a number, string, list, boolean, or nobody to an opened file, *not* followed by a carriage return (unlike file−print and file−show).

The calling agent is *not* printed before the value, unlike file−show. Its output also includes quotes around strings and is prepended with a space. It will output the value in such a manner that file−read will be able to interpret it.

Note that this command is the file i/o equivalent of write, and file−open needs to be called before this command can be used.

```
file−open "locations.txt"
ask turtles
  [ file−write xcor file−write ycor ]
```

See also file−print, file−show, and file−type.

---

filter

filter [*reporter*] *list*

Reports a list containing only those items of *list* for which the boolean *reporter* is true −− in other words, the items satisfying the given condition.

In *reporter*, use ? to refer to the current item of *list*.

```
show filter [? < 3] [1 3 2]
=> [1 2]
show filter [first ? != "t"] ["hi" "there" "everyone"]
=> ["hi" "everyone"]
```

See also map, reduce, ?.

first

first *list*
first *string*

On a list, reports the first (0th) item in the list.

On a string, reports a one−character string containing only the first character of the original string.

floor

floor *number*

Reports the largest integer less than or equal to *number*.

```
show floor 4.5
=> 4
show floor −4.5
=> −5
```

follow

follow *turtle*

Similar to ride, but, in the 3D view, the observer's vantage point is behind and above *turtle*.

See also follow−me, ride, reset−perspective, watch, subject.

follow−me

follow−me

Asks the observer to follow the calling turtle.

See also follow.

foreach

foreach *list* [*commands*]
(foreach *list1* ... [*commands*])

With a single list, runs *commands* for each item of *list*. In *commands*, use ? to refer to the current item of *list*.

```
foreach [1.1 2.2 2.6] [ show (word ? " -> " round ?) ]
=> 1.1 -> 1
=> 2.2 -> 2
=> 2.6 -> 3
```

With multiple lists, runs *commands* for each group of items from each list. So, they are run once for the first items, once for the second items, and so on. All the lists must be the same length. In *commands*, use ?1 through ?n to refer to the current item of each list.

Some examples make this clearer:

```
(foreach [1 2 3] [2 4 6]
   [ show word "the sum is: " (?1 + ?2) ])
=> "the sum is: 3"
=> "the sum is: 6"
=> "the sum is: 9"
(foreach list (turtle 1) (turtle 2) [3 4]
  [ ask ?1 [ fd ?2 ] ])
;; turtle 1 moves forward 3 patches
;; turtle 2 moves forward 4 patches
```

See also map, ?.

---

forward
fd

forward *number*

The turtle moves forward by *number* steps, one step at a time. (If *number* is negative, the turtle moves backward.)

`fd 10` is equivalent to `repeat 10 [ jump 1 ]`. `fd 10.5` is equivalent to `repeat 10 [ jump 1 ] jump 0.5`.

If the turtle cannot move forward *number* steps because it is not permitted by the current topology the turtle will complete as many steps of 1 as it can, then stop.

See also jump, can-move?.

---

fput

fput *item list*

Adds *item* to the beginning of a list and reports the new list.

```
;; suppose mylist is [5 7 10]
set mylist fput 2 mylist
;; mylist is now [2 5 7 10]
```

G

globals

globals [*var1* ...]

This keyword, like the breed, <*breeds*>−own, patches−own, and turtles−own keywords, can only be used at the beginning of a program, before any function definitions. It defines new global variables. Global variables are "global" because they are accessible by all agents and can be used anywhere in a model.

Most often, globals is used to define variables or constants that need to be used in many parts of the program.

H

hatch
hatch−<*breeds*>

hatch *number* [*commands*]
hatch−<*breeds*> *number* [*commands*]

This turtle creates *number* new turtles. Each new turtle is identical to, and at the same location as, its parent. The new turtles then run *commands*. You can use the commands to give the new turtles different colors, headings, locations, or whatever. (The new turtles are created all at once, then run one at a time, in random order.)

If the hatch−<*breeds*> form is used, the new turtles are created as members of the given breed. Otherwise, the new turtles are the same breed as their parent.

Note: While the commands are running, no other agents are allowed to run any code (as with the `without−interruption` command). This ensures that if `ask−concurrent` is being used, the new turtles cannot interact with any other agents until they are fully initialized.

```
hatch 1 [ lt 45 fd 1 ]
;; this turtle creates one new turtle,
;; and the child turns and moves away
hatch−sheep 1 [ set color black ]
;; this turtle creates a new turtle
;; of the sheep breed
```

See also create−turtles, sprout.

heading

heading

This is a built−in turtle variable. It indicates the direction the turtle is facing. This is a number greater than or equal to 0 and less than 360. 0 is north, 90 is east, and so on. You can set this variable to make a turtle turn.

See also right, left, dx, dy.

Example:

```
set heading 45      ;; turtle is now facing northeast
set heading heading + 10 ;; same effect as "rt 10"
```

---

hidden?

hidden?

This is a built−in turtle or link variable. It holds a boolean (true or false) value indicating whether the turtle or link is currently hidden (i.e., invisible). You can set this variable to make a turtle or link disappear or reappear.

See also hide−turtle, show−turtle, hide−link, show−link

Example:

```
set hidden? not hidden?
;; if turtle was showing, it hides, and if it was hiding,
;; it reappears
```

---

hide−link

hide−link

The link makes itself invisible.

Note: This command is equivalent to setting the link variable "hidden?" to true.

See also show−link.

---

hide−turtle
ht

hide−turtle

The turtle makes itself invisible.

Note: This command is equivalent to setting the turtle variable "hidden?" to true.

See also show−turtle.

histogram

histogram *list*

Histograms the values in the given list

Draws a histogram showing the frequency distribution of the values in the list. The heights of the bars in the histogram represent the numbers of values in each subrange.

Before the histogram is drawn, first any previous points drawn by the current plot pen are removed.

Any non−numeric values in the list are ignored.

The histogram is drawn on the current plot using the current plot pen and pen color. Use set−plot−x−range to control the range of values to be histogrammed, and set the pen interval (either directly with set−plot−pen−interval, or indirectly via set−histogram−num−bars) to control how many bars that range is split up into.

Be sure that if you want the histogram drawn with bars that the current pen is in bar mode (mode 1).

For histogramming purposes the plot's X range is not considered to include the maximum X value. Values equal to the maximum X will fall outside of the histogram's range.

```
histogram [color] of turtles
;; draws a histogram showing how many turtles there are
;; of each color
```

home

home

The calling turtles moves to the origin (0,0). Equivalent to `setxy 0 0`.

hsb

hsb *hue saturation brightness*

Reports a RGB list when given a color in HSB format. Hue, saturation, and brightness are integers in the range 0−255. The RGB list contains three integers in the same range.

See also rgb

hubnet−broadcast

hubnet−broadcast *tag−name value*

This broadcasts *value* from NetLogo to the variable, in the case of Calculator HubNet, or interface element, in the case of Computer HubNet, with the name *tag−name* to the clients.

See the HubNet Authoring Guide for details and instructions.

hubnet−broadcast−view

hubnet−broadcast−view

This broadcasts the current state of the 2D view in the NetLogo model to all the Computer HubNet Clients. It does nothing for Calculator HubNet.

Note: This is an experimental primitive and its behavior may change in a future version.

See the HubNet Authoring Guide for details and instructions.

hubnet−enter−message?

hubnet−enter−message?

Reports true if a new computer client just entered the simulation. Reports false otherwise. hubnet−message−source will contain the user name of the client that just logged on.

See the HubNet Authoring Guide for details and instructions.

hubnet−exit−message?

hubnet−exit−message?

Reports true if a computer client just exited the simulation. Reports false otherwise. hubnet−message−source will contain the user name of the client that just logged off.

See the HubNet Authoring Guide for details and instructions.

hubnet−fetch−message

hubnet−fetch−message

If there is any new data sent by the clients, this retrieves the next piece of data, so that it can be accessed by hubnet−message, hubnet−message−source, and hubnet−message−tag. This will cause an error if there is no new data from the clients.

See the HubNet Authoring Guide for details.

hubnet−message

hubnet−message

Reports the message retrieved by hubnet−fetch−message.

See the HubNet Authoring Guide for details.

hubnet−message−source

hubnet−message−source

Reports the name of the client that sent the message retrieved by hubnet−fetch−message.

See the HubNet Authoring Guide for details.

hubnet−message−tag

hubnet−message−tag

Reports the tag that is associated with the data that was retrieved by hubnet−fetch−message. For Calculator HubNet, this will report one of the variable names set with the hubnet−set−client−interface primitive. For Computer HubNet, this will report one of the Display Names of the interface elements in the client interface.

See the HubNet Authoring Guide for details.

hubnet−message−waiting?

hubnet−message−waiting?

This looks for a new message sent by the clients. It reports true if there is one, and false if there is not.

See the HubNet Authoring Guide for details.

hubnet−reset

hubnet−reset

Starts up the HubNet system. HubNet must be started to use any of the other hubnet primitives with the exception of `hubnet−set−client−interface`.

See the HubNet Authoring Guide for details.

hubnet−send

hubnet−send *string tag−name value*

hubnet−send *list−of−strings tag−name value*

For Calculator HubNet, this primitive acts in exactly the same manner as hubnet−broadcast. (We plan to change this in a future version of NetLogo.)

For Computer HubNet, it acts as follows:

For a *string*, this sends *value* from NetLogo to the tag *tag−name* on the client that has *string* for its user name.

For a *list−of−strings*, this sends *value* from NetLogo to the tag *tag−name* on all the clients that have a user name that is in the *list−of−strings*.

Sending a message to a non−existent client, using `hubnet−send`, generates a `hubnet−exit−message`.

See the HubNet Authoring Guide for details.

---

hubnet−send−view

hubnet−send−view *string*

hubnet−send−view *list−of−strings*

For Calculator HubNet, does nothing.

For Computer HubNet, it acts as follows:

For a *string*, this sends the current state of the 2D view in the NetLogo model to the Computer HubNet Client with *string* for its user name.

For a *list−of−strings*, this sends the current state of the view in the NetLogo model to all the Computer HubNet Clients that have a user name that is in the *list−of−strings*.

Sending the 2D view to a nonexistent client, using `hubnet−send−view`, generates a `hubnet−exit−message`.

Note: This is an experimental primitive and its behavior may change in a future version.

See the HubNet Authoring Guide for details.

---

hubnet−set−client−interface

hubnet−set−client−interface *client−type client−info*

If *client−type* is "COMPUTER", *client−info* is an empty list for computer HubNet.

```
hubnet−set−client−interface "COMPUTER"[]
```

Future versions of HubNet will support other client types. Even for Computer HubNet, the meaning of the second input to this command may change.

See the HubNet Authoring Guide for details.

I

if

if *condition* [*commands*]

Reporter must report a boolean (true or false) value.

If *condition* reports true, runs *commands*.

The reporter may report a different value for different agents, so some agents may run *commands* and others don't.

```
if xcor > 0[ set color blue ]
;; turtles in the right half of the world
;; turn blue
```

See also ifelse, ifelse−value.

ifelse

ifelse *reporter* [*commands1*] [*commands2*]

Reporter must report a boolean (true or false) value.

If *reporter* reports true, runs *commands1*.

If *reporter* reports false, runs *commands2*.

The reporter may report a different value for different agents, so some agents may run *commands1* while others run *commands2*.

```
ask patches
  [ ifelse pxcor > 0
      [ set pcolor blue ]
      [ set pcolor red ] ]
;; the left half of the world turns red and
;; the right half turns blue
```

See also if, ifelse−value.

ifelse−value

ifelse−value *reporter* [*reporter1*] [*reporter2*]

Reporter must report a boolean (true or false) value.

If *reporter* reports true, the result is the value of *reporter1*.

If *reporter* reports false, the result is the value of *reporter2*.

This can be used when a conditional is needed in the context of a reporter, where commands (such as ifelse) are not allowed.

```
ask patches [
  set pcolor ifelse−value (pxcor > 0) [blue] [red]
]
;; the left half of the world turns red and
;; the right half turns blue
show n−values 10 [ifelse−value (? < 5) [0] [1]]
=> [0 0 0 0 0 1 1 1 1 1]
show reduce [ifelse−value (?1 > ?2) [?1] [?2]]
  [1 3 2 5 3 8 3 2 1]
=> 8
```

See also if, ifelse.

import−drawing

import−drawing *filename*

Reads an image file into the drawing, scaling it to the size of the world, while retaining the original aspect ratio of the image. The image is centered in the drawing. The old drawing is not cleared first.

Agents cannot sense the drawing, so they cannot interact with or process images imported by import−drawing. If you need agents to sense an image, use import−pcolors or import−pcolors−rgb.

The following image file formats are supported: BMP, JPG, GIF, and PNG. If the image format supports transparency (alpha), that information will be imported as well.

import−pcolors

import−pcolors *filename*

Reads an image file, scales it to the same dimensions as the patch grid while maintaining the original aspect ratio of the image, and transfers the resulting pixel colors to the patches. The image is centered in the patch grid. The resulting patch colors may be distorted, since the NetLogo color space does not include all possible colors. (See the Color section of the Programming Guide.) import−pcolors may be slow for some images, particularly when you have many patches and a large

image with many different colors.

Since import−pcolors sets the pcolor of patches, agents can sense the image. This is useful if agents need to analyze, process, or otherwise interact with the image. If you want to simply display a static backdrop, without color distortion, see import−drawing.

The following image file formats are supported: BMP, JPG, GIF, and PNG. If the image format supports transparency (alpha), then all fully transparent pixels will be ignored. (Partially transparent pixels will be treated as opaque.)

---

import−pcolors−rgb

import−pcolors−rgb *filename*

Reads an image file, scales it to the same dimensions as the patch grid while maintaining the original aspect ratio of the image, and transfers the resulting pixel colors to the patches. The image is centered in the patch grid. Unlike import−pcolors the exact colors in the original image are retained. The pcolor variable of all the patches will be an RGB list rather than an (approximated) NetLogo color.

The following image file formats are supported: BMP, JPG, GIF, and PNG. If the image format supports transparency (alpha), then all fully transparent pixels will be ignored. (Partially transparent pixels will be treated as opaque.)

---

import−world

import−world *filename*

Reads the values of all variables for a model, both built−in and user−defined, including all observer, turtle, and patch variables, from an external file named by the given string. The file should be in the format used by the export−world primitive.

Note that the functionality of this primitive is also directly available from NetLogo's File menu.

When using import−world, to avoid errors, perform these steps in the following order:

1. Open the model from which you created the export file.
2. Press the Setup button, to get the model in a state from which it can be run.
3. Import the file.
4. Re−open any files that the model had opened with the `file−open` command.
5. If you want, press Go button to continue running the model from the point where it left off.

If you wish to import a file from a location other than the model's location, you may include the full path to the file you wish to import. See export−world for an example.

---

in−cone

agentset* in−cone *distance angle

This reporter lets you give a turtle a "cone of vision" in front of itself. The cone is defined by the two inputs, the vision distance (radius) and the viewing angle. The viewing angle may range from 0 to 360 and is centered around the turtle's current heading. (If the angle is 360, then in−cone is equivalent to in−radius.)

in−cone reports an agentset that includes only those agents from the original agentset that fall in the cone. (This can include the calling agent itself.)

The distance to a patch is measured from the center of the patch.

```
ask turtles
  [ ask patches in-cone 3 60
      [ set pcolor red ] ]
;; each turtle makes a red "splotch" of patches in a 60 degree
;; cone of radius 3 ahead of itself
```

---

in−<breed>−neighbor?
in−link−neighbor?

in−<breed>−neighbor? *agent*
in−link−neighbor? *turtle*

Reports true if there is a directed link going from *turtle* to the caller.

```
crt 2
ask turtle 0 [
  create-link-to turtle 1
  show in-link-neighbor? turtle 1  ;; prints false
  show out-link-neighbor? turtle 1 ;; prints true
]
ask turtle 1 [
  show in-link-neighbor? turtle 0  ;; prints true
  show out-link-neighbor? turtle 0 ;; prints false
]
```

---

in−<breed>−neighbors
in−link−neighbors

in−<breed>−neighbors
in−link−neighbors

Reports the agentset of all the turtles that have directed links coming from them to the caller.

```
crt 4
ask turtle 0 [ create-links-to other turtles ]
```

```
ask turtle 1 [ ask in-link-neighbors [ set color blue ] ] ;; turtle 0 turns blue
```

in-<breed>-from
in-link-from

in-<breed>-from *turtle*
in-link-from *turtle*

Report the link from *turtle* to the caller. If no link exists then it reports nobody.

```
crt 2
ask turtle 0 [ create-link-to turtle 1 ]
ask turtle 1 [ show in-link-from turtle 0 ] ;; shows link 0 1
ask turtle 0 [ show in-link-from turtle 1 ] ;; shows nobody
```

__includes

__includes [*filename* ...]

Causes external NetLogo source files (with the `.nls` suffix) to be included in this model. Included files may contain breed, variable, and procedure definitions. `__includes` can only be used once per file.

in-radius

agentset* in-radius *number

Reports an agentset that includes only those agents from the original agentset whose distance from the caller is less than or equal to *number*. (This can include the calling agent itself.)

The distance to or a from a patch is measured from the center of the patch.

```
ask turtles
  [ ask patches in-radius 3
      [ set pcolor red ] ]
;; each turtle makes a red "splotch" around itself
```

inspect

inspect *agent*

Opens an agent monitor for the given agent (turtle or patch).

```
inspect patch 2 4
;; an agent monitor opens for that patch
inspect one-of sheep
;; an agent monitor opens for a random turtle from
;; the "sheep" breed
```

int

int *number*

Reports the integer part of number −− any fractional part is discarded.

```
show int 4.7
=> 4
show int −3.5
=> −3
```

---

is−agent?
is−agentset?
is−boolean?
is−<*breed*>?
is−directed−link?
is−link?
is−link−set?
is−list?
is−number?
is−patch?
is−patch−set?
is−string?
is−turtle?
is−turtle−set?
is−undirected−link?

is−agent? *value*
is−agentset? *value*
is−boolean? *value*
is−<*breed*>? *value*
is−directed−link? *value*
is−link? *value*
is−link−set? *value*
is−list? *value*
is−number? *value*
is−patch? *value*
is−patch−set? *value*
is−string? *value*
is−turtle? *value*
is−turtle−set? *value*
is−directed−link? *value*

Reports true if *value* is of the given type, false otherwise.

---

item

item *index list*
item *index string*

On lists, reports the value of the item in the given list with the given index.

On strings, reports the character in the given string at the given index.

Note that the indices begin from 0, not 1. (The first item is item 0, the second item is item 1, and so on.)

```
;; suppose mylist is [2 4 6 8 10]
show item 2 mylist
=> 6
show item 3 "my−shoe"
=> "s"
```

J

jump

jump *number*

The turtle moves forward by *number* units all at once (rather than one step at a time as with the `forward` command).

If the turtle cannot jump *number* units because it is not permitted by the current topology the turtle does not move at all.

See also forward, can−move?.

L

label

label

This is a built−in turtle or link variable. It may hold a value of any type. The turtle or link appears in the view with the given value "attached" to it as text. You can set this variable to add, change, or remove a turtle or link's label.

See also label−color, plabel, plabel−color.

Example:

```
ask turtles [ set label who ]
;; all the turtles now are labeled with their
```

```
;; who numbers
ask turtles [ set label "" ]
;; all turtles now are not labeled
```

label−color

label−color

This is a built−in turtle or link variable. It holds a number greater than or equal to 0 and less than 140. This number determines what color the turtle or link's label appears in (if it has a label). You can set this variable to change the color of a turtle or link's label.

See also label, plabel, plabel−color.

Example:

```
ask turtles [ set label−color red ]
;; all the turtles now have red labels
```

last

last *list*
last *string*

On a list, reports the last item in the list.

On a string, reports a one−character string containing only the last character of the original string.

layout−circle

layout−circle *agentset radius*
layout−circle *list−of−turtles radius*

Arranges the given turtles in a circle centered on the patch at the center of the world with the given radius. (If the world has an even size the center of the circle is rounded down to the nearest patch.) The turtles point outwards.

If the first input is an agentset, the turtles are arranged in random order.

If the first input is a list, the turtles are arranged clockwise in the given order, starting at the top of the circle. (Any non−turtles in the list are ignored.)

```
;; in random order
layout−circle turtles 10
;; in order by who number
layout−circle sort turtles 10
;; in order by size
layout−circle sort−by [[size] of ?1 < [size] of ?2] turtles 10
```

__layout−magspring

__layout−magspring *turtle−set link−set spring−constant spring−length repulsion−constant magnetic−field−strength magnetic−field−type bidirectional?*

Very similar to layout−spring, but with an added layer of complexity. The turtles in *turtle−set* attract and repel each other depending on the links (that are in *link−set*) between them, but there is also a magnetic field which the links try to align with.

The *link−set* is the set of links that exert forces on the turtles they are connected to. Turtles that are connected to links in the link agentset but are not included in the turtle agentset are treated as anchors. If there are no turtles with fixed positions the entire network will probably collapse on itself.

spring−constant is a measure of the "tautness" of the spring. (See layout−spring)

spring−length is the "zero−force" length or the natural length of the springs. (See layout−spring)

repulsion−constant is a measure of repulsion between the nodes. (See layout−spring)

magnetic−field−strength is the force of the magnetic field. (Reasonable values range from 0 to 1, but 0.05 is a good default.)

magnetic−field−type is a number in the range from 0 to 10. Choices are listed in the table below.

magnetic−field−type	Description
NONE = 0	If no field is used, then this command works just like layout−spring.
NORTH = 1	Magnetic field runs toward the North
NORTHEAST = 2	Magnetic field runs toward the Northeast
EAST = 3	...
SOUTHEAST= 4	...
SOUTH = 5	...
SOUTHWEST= 6	...
WEST = 7	...
NORTHWEST = 8	...
POLAR = 9	Magnetic field runs outward at all angles from the origin.
CONCENTRIC = 10	Magnetic field runs clockwise around the origin in concentric circles.

If *bidirectional?* is true then links try to align with the magnetic field by pushing attached turtles both in the direction of the field, and in the opposite direction. Otherwise, the links just push in a single direction.

```
to make−a−tree
  set−default−shape turtles "circle"
```

```
  crt 5
  ask turtle 0 [
    create-link-with turtle 1
    create-link-with turtle 2
  ]
  ask turtle 1 [
    create-link-with turtle 3
    create-link-with turtle 4
  ]
  ; layout with a fairly strong SOUTH magnetic field
  repeat 50 [ __layout-magspring
              turtles with [who != 0] links 0.3 4 1 .50 5 false ]
end
```

layout−radial

layout−radial *turtle−set link−set root−agent*

Arranges the turtles in *turtle−set* connected by links in *link−set*, in a radial tree layout, centered around the *root−agent* which is moved to the center of the world view.

Only links in the *link−set* will be used to determine the layout. If links connect turtles that are not in *turtle−set* those turtles will remain stationary.

Even if the network does contain cycles, and is not a true tree structure, this layout will still work, although the results will not always be pretty.

```
to make-a-tree
  set-default-shape turtles "circle"
  crt 6
  ask turtle 0 [
    create-link-with turtle 1
    create-link-with turtle 2
    create-link-with turtle 3
  ]
  ask turtle 1 [
    create-link-with turtle 4
    create-link-with turtle 5
  ]
  ; do a radial tree layout, centered on turtle 0
  layout-radial turtles (turtle 0) links
end
```

layout−spring

layout−spring *turtle−set link−set spring−constant spring−length repulsion−constant*

Arranges the turtles in *turtle−set*, as if the links in *link−set* are springs and the turtles are repelling each other. Turtles that are connected by links in *link−set* but not included in *turtle−set* are treated as anchors and are not moved.

spring−constant is a measure of the "tautness" of the spring. It is the "resistance" to change in their length. spring−constant is the force the spring would exert if it's length were changed by 1 unit.

spring−length is the "zero−force" length or the natural length of the springs. This is the length which all springs try to achieve either by pushing out their nodes or pulling them in.

repulsion−constant is a measure of repulsion between the nodes. It is the force that 2 nodes at a distance of 1 unit will exert on each other.

The repulsion effect tries to get the nodes as far as possible from each other, in order to avoid crowding and the spring effect tries to keep them at "about" a certain distance from the nodes they are connected to. The result is the laying out of the whole network in a way which highlights relationships among the nodes and at the same time is crowded less and is visually pleasing.

The layout algorithm is based on the Fruchterman−Reingold layout algorithm. More information about this algorithm can be obtained here.

```
to make−a−triangle
  set−default−shape turtles "circle"
  crt 3
  ask turtle 0
  [
    create−links−with other turtles
  ]
  ask turtle 1
  [
    create−link−with turtle 2
  ]
  repeat 30 [ layout−spring turtles links 0.2 5 1 ] ;; lays the nodes in a triangle
end
```

layout−tutte

layout−tutte *turtle−set link−set radius*

The turtles that are connected by links in *link−set* but not included in *turtle−set* are placed in a circle layout with the given *radius*. There should be at least 3 agents in this agentset.

The turtles in *turtle−set* are then laid out in the following manner: Each turtle is placed at centroid (or barycenter) of the polygon formed by its linked neighbors. (The centroid is like a 2−dimensional average of the coordinates of the neighbors.)

(The purpose of the circle of "anchor agents" is to prevent all the turtles from collapsing down to one point.)

After a few iterations of this, the layout will stabilize.

This layout is named after the mathematician William Thomas Tutte, who proposed it as a method for graph layout.

```
to make−a−tree
  set−default−shape turtles "circle"
  crt 6
  ask turtle 0 [
    create−link−with turtle 1
    create−link−with turtle 2
    create−link−with turtle 3
```

```
  ]
  ask turtle 1 [
    create-link-with turtle 4
    create-link-with turtle 5
  ]
  ; place all the turtles with just one
  ; neighbor on the perimeter of a circle
  ; and then place the remaining turtles inside
  ; this circle, spread between their neighbors.
  repeat 10 [ layout-tutte turtles
              (turtles with [count link-neighbors = 1]) 12 ]
end
```

left
lt

left *number*

The turtle turns left by *number* degrees. (If *number* is negative, it turns right.)

length

length *list*
length *string*

Reports the number of items in the given list, or the number of characters in the given string.

let

let *variable value*

Creates a new local variable and gives it the given value. A local variable is one that exists only within the enclosing block of commands.

If you want to change the value afterwards, use set.

Example:

```
let prey one-of sheep-here
if prey != nobody
  [ ask prey [ die ] ]
```

link

link *end1 end2* <breed> *end1 end2*

Given the who numbers of the endpoints, reports the link connecting the turtles. If there is no such link reports `nobody`. To refer to breeded links you must use the singular breed form with the endpoints.

```
ask link 0 1 [ set color green ]
```

```
;; unbreeded link connecting turtle 0 and turtle 1 will turn green
ask directed-link 0 1 [ set color red ]
;; directed link connecting turtle 0 and turtle 1 will turn red
```

See also patch-at.

link-heading

link-heading

Reports the heading in degrees (at least 0, less than 360) from `end1` to `end2` of the link.

```
ask link 0 1 [ print link-heading ]
;; prints [[towards other-end] of end1] of link 0 1
```

See also link-length

link-length

link-length

Reports the distance between the endpoints of the link.

```
ask link 0 1 [ print link-length ]
;; prints [[distance other-end] of end1] of link 0 1
```

See also link-heading

link-set

link-set *value*
(link-set *value1 value2* ...)

Reports an agentset containing all of the links anywhere in any of the inputs. The inputs may be individual links, link agentsets, nobody, or lists (or nested lists) containing any of the above.

```
link-set self
link-set [my-links] of nodes with [color = red]
```

See also turtle-set, patch-set.

links

links

Reports the agentset consisting of all links.

```
show count links
;; prints the number of links
```

links−own
<link−breeds>−own

links−own [*var1* ...]
<*link−breeds*>−own [*var1* ...]

The links−own keyword, like the globals, breed, <*breeds*>−own, turtles−own, and patches−own keywords, can only be used at the beginning of a program, before any function definitions. It defines the variables belonging to each link.

If you specify a breed instead of "links", only links of that breed have the listed variables. (More than one breed may list the same variable.)

```
undirected−link−breed [sidewalks sidewalk]
directed−link−breed [streets street]
links−own [traffic]   ;; applies to all breeds
sidewalks−own [pedestrians]
streets−own [cars bikes]
```

list

list *value1 value2*
(list *value1* ...)

Reports a list containing the given items. The items can be of any type, produced by any kind of reporter.

```
show list (random 10) (random 10)
=> [4 9]  ;; or similar list
show (list 5)
=> [5]
show (list (random 10) 1 2 3 (random 10))
=> [4 1 2 3 9]  ;; or similar list
```

ln

ln *number*

Reports the natural logarithm of *number*, that is, the logarithm to the base e (2.71828...).

See also e, log.

log

log *number base*

Reports the logarithm of *number* in base *base*.

```
show log 64 2
=> 6
```

See also ln.

loop

loop [*commands*]

Runs the list of commands forever, or until the current procedure exits through use of the stop command or the report command.

Note: In most circumstances, you should use a forever button in order to repeat something forever. The advantage of using a forever button is that the user can click the button to stop the loop.

lput

lput *value list*

Adds *value* to the end of a list and reports the new list.

```
;; suppose mylist is [2 7 10 "Bob"]
set mylist lput 42 mylist
;; mylist now is [2 7 10 "Bob" 42]
```

M

map

map [*reporter*] *list*
(map [*reporter*] *list1* ...)

With a single *list*, the given reporter is run for each item in the list, and a list of the results is collected and reported.

In *reporter*, use ? to refer to the current item of *list*.

```
show map [round ?] [1.1 2.2 2.7]
=> [1 2 3]
show map [? * ?] [1 2 3]
=> [1 4 9]
```

With multiple lists, the given reporter is run for each group of items from each list. So, it is run once for the first items, once for the second items, and so on. All the lists must be the same length.

In *reporter*, use ?1 through ?n to refer to the current item of each list.

Some examples make this clearer:

```
show (map [?1 + ?2] [1 2 3] [2 4 6])
=> [3 6 9]
show (map [?1 + ?2 = ?3] [1 2 3] [2 4 6] [3 5 9])
=> [true false true]
```

See also foreach, ?.

max

max *list*

Reports the maximum number value in the list. It ignores other types of items.

```
show max [xcor] of turtles
;; prints the x coordinate of the turtle which is
;; farthest right in the world
```

max−one−of

max−one−of *agentset* [*reporter*]

Reports the agent in the agentset that has the highest value for the given reporter. If there is a tie this command reports one random agent with the highest value. If you want all such agents, use with−max instead.

```
show max−one−of patches [count turtles−here]


;; prints the first patch with the most turtles on it
```

See also with−max

max−pxcor
max−pycor

max−pxcor
max−pycor

These reporters give the maximum x−coordinate and maximum y−coordinate, (respectively) for patches, which determines the size of the world.

Unlike in older versions of NetLogo the origin does not have to be at the center of the world. However, the maximum x− and y− coordinates must be greater than or equal to zero.

Note: You can set the size of the world only by editing the view −− these are reporters which cannot be set.

```
crt 100 [ setxy random−float max−pxcor
                random−float max−pycor ]
;; distributes 100 turtles randomly in the
;; first quadrant
```

See also min−pxcor, min−pycor, world−width, and world−height

mean

mean *list*

Reports the statistical mean of the numeric items in the given list. Ignores non−numeric items. The mean is the average, i.e., the sum of the items divided by the total number of items.

```
show mean [xcor] of turtles
;; prints the average of all the turtles' x coordinates
```

---

median

median *list*

Reports the statistical median of the numeric items of the given list. Ignores non−numeric items. The median is the item that would be in the middle if all the items were arranged in order. (If two items would be in the middle, the median is the average of the two.)

```
show median [xcor] of turtles
;; prints the median of all the turtles' x coordinates
```

---

member?

member? *value list*
member? *string1 string2*
member? *agent agentset*

For a list, reports true if the given value appears in the given list, otherwise reports false.

For a string, reports true or false depending on whether *string1* appears anywhere inside *string2* as a substring.

For an agentset, reports true if the given agent is appears in the given agentset, otherwise reports false.

```
show member? 2 [1 2 3]
=> true
show member? 4 [1 2 3]
=> false
show member? "bat" "abate"
=> true
show member? turtle 0 turtles
=> true
show member? turtle 0 patches
=> false
```

See also position.

---

min

min *list*

Reports the minimum number value in the list. It ignores other types of items.

```
show min [xcor] of turtles
;; prints the lowest x−coordinate of all the turtles
```

---

min−one−of

min−one−of *agentset* [*reporter*]

Reports a random agent in the agentset that reports the lowest value for the given reporter. If there is a tie, this command reports one random agent that meets the condition. If you want all such agents use with−min instead.

```
show min−one−of turtles [xcor + ycor]
;; reports the first turtle with the smallest sum of
;; coordinates
```

See also with−min

---

min−pxcor
min−pycor

min−pxcor
min−pycor

These reporters give the minimum x−coordinate and minimum y−coordinate, (respectively) for patches, which determines the size of the world.

Unlike in older versions of NetLogo the origin does not have to be at the center of the world. However, the minimum x− and y− coordinates must be less than or equal to zero.

Note: You can set the size of the world only by editing the view −− these are reporters which cannot be set.

```
crt 100 [ setxy random−float min−pxcor
                random−float min−pycor ]
;; distributes 100 turtles randomly in the
;; third quadrant
```

See also max−pxcor, max−pycor, world−width, and world−height

---

mod

number1* mod *number2

Reports *number1* modulo *number2*: that is, the residue of *number1* (mod *number2*). mod is is equivalent to the following NetLogo code:

```
number1 − (floor (number1 / number2)) * number2
```

Note that mod is "infix", that is, it comes between its two inputs.

```
show 62 mod 5
=> 2
show −8 mod 3
=> 1
```

See also remainder. mod and remainder behave the same for positive numbers, but differently for negative numbers.

modes

modes *list*

Reports a list of the most common item or items in *list*.

The input list may contain any NetLogo values.

If the input is an empty list, reports an empty list.

```
show modes [1 2 2 3 4]
=> [2]
show modes [1 2 2 3 3 4]
=> [2 3]
show modes [ [1 2 [3]] [1 2 [3]] [2 3 4] ]
=> [[1 2 [3]]
show modes [pxcor] of turtles
;; shows which columns of patches have the most
;; turtles on them
```

mouse−down?

mouse−down?

Reports true if the mouse button is down, false otherwise.

Note: If the mouse pointer is outside of the current view , mouse−down? will always report false.

mouse−inside?

mouse−inside?

Reports true if the mouse pointer is inside the current view, false otherwise.

mouse−patch

mouse−patch

Reports a patch if the mouse pointer is pointing to one; otherwise, reports nobody.

mouse−xcor
mouse−ycor

mouse−xcor
mouse−ycor

Reports the x or y coordinate of the mouse in the 2D view. The value is in terms of turtle coordinates, so it might not be an integer. If you want patch coordinates, use `round mouse−xcor` and `round mouse−ycor`.

Note: If the mouse is outside of the 2D view, reports the value from the last time it was inside.

```
;; to make the mouse "draw" in red:
if mouse−down?
  [ ask patch mouse−xcor mouse−ycor [ set pcolor red ] ]
```

move−to

move−to *agent*

The turtle sets its x and y coordinates to be the same as the given agent's.

(If that agent is a patch, the effect is to move the turtle to the center of that patch.)

```
move−to turtle 5
;; turtle moves to same point as turtle 5
move−to one−of patches
;; turtle moves to the center of a random patch
move−to max−one−of turtles [size]
;; turtle moves to same point as biggest turtle
```

Note that the turtle's heading is unaltered. You may want to use the face command first to orient the turtle in the direction of motion.

See also setxy.

movie−cancel

movie−cancel

Cancels the current movie.

movie−close

movie−close

Stops the recording of the current movie.

movie−grab−view
movie−grab−interface

movie−grab−view
movie−grab−interface

Adds an image of the current view or the interface panel to the current movie.

```
;; make a 20−step movie of the current view
setup
movie−start "out.mov"
repeat 20 [
  movie−grab−view
  go
]
movie−close
```

---

movie−set−frame−rate

movie−set−frame−rate *frame−rate*

Sets the frame rate of the current movie. The frame rate is measured in frames per second. (If you do not explicitly set the frame rate, it defaults to 15 frames per second.)

Must be called after movie−start, but before movie−grab−view or movie−grab−interface.

See also movie−status.

---

movie−start

movie−start *filename*

Creates a new movie. *filename* specifies a new QuickTime file where the movie will be saved, so it should end with "`.mov`".

See also movie−grab−view, movie−grab−interface, movie−cancel, movie−status, movie−set−frame−rate, movie−close.

---

movie−status

movie−status

Reports a string describing the current movie.

```
print movie−status
=> No movie.
movie−start
print movie−status
=> 0 frames; frame rate = 15.
movie−grab−view
print movie−status
1 frames; frame rate = 15; size = 315x315.
```

my−<breeds>
my−links

my−<breeds>
my−links

Reports an agentset of all undirected links connected to the caller.

```
crt 5
ask turtle 0
[
  create−links−with other turtles
  show my−links ;; prints the agentset containing all links
                ;; (since all the links we created were with turtle 0 )
]
ask turtle 1
[
  show my−links ;; shows an agentset containing the link 0 1
]
end
```

my−in−<breeds>
my−in−links

my−in−<breeds>
my−in−links

Reports an agentset of all the directed links coming in from other nodes to the caller.

```
crt 5
ask turtle 0
[
  create−links−to other turtles
  show my−in−links ;; shows an empty agentset
]
ask turtle 1
[
  show my−in−links ;; shows an agentset containing the link 0 1
]
```

my−out−<breeds>
my−out−links

my−out−<breeds>
my−out−links

Reports an agentset of all the directed links going out from the caller to other nodes.

```
crt 5
```

```
ask turtle 0
[
  create-links-to other turtles
  show my-out-links ;; shows agentset containing all the links
]
ask turtle 1
[
  show my-out-links ;; shows an empty agentset
]
```

myself

myself

"self" and "myself" are very different. "self" is simple; it means "me". "myself" means "the turtle or patch who asked me to do what I'm doing right now."

When an agent has been asked to run some code, using myself in that code reports the agent (turtle or patch) that did the asking.

myself is most often used in conjunction with `of` to read or set variables in the asking agent.

myself can be used within blocks of code not just in the ask command, but also hatch, sprout, of, with, min-one-of, and max-one-of.

```
ask turtles
  [ ask patches in-radius 3
      [ set pcolor [color] of myself ] ]
;; each turtle makes a colored "splotch" around itself
```

See the "Myself Example" code example for more examples.

See also self.

N

n-of

n-of *size agentset*
n-of *size list*

From an agentset, reports an agentset of size *size* randomly chosen from the input set, with no repeats.

From a list, reports a list of size *size* randomly chosen from the input set, with no repeats. The items in the result appear in the same order that they appeared in the input list. (If you want them in random order, use shuffle on the result.)

It is an error for *size* to be greater than the size of the input.

```
ask n-of 50 patches [ set pcolor green ]
```

```
;; 50 randomly chosen patches turn green
```

See also one−of.

---

n−values

n−values *size* [*reporter*]

Reports a list of length *size* containing values computed by repeatedly running *reporter*.

In *reporter*, use ? to refer to the number of the item currently being computed, starting from zero.

```
show n−values 5 [1]
=> [1 1 1 1 1]
show n−values 5 [?]
=> [0 1 2 3 4]
show n−values 3 [turtle ?]
=> [(turtle 0) (turtle 1) (turtle 2)]
show n−values 5 [? * ?]
=> [0 1 4 9 16]
```

See also reduce, filter, ?.

---

neighbors
neighbors4

neighbors
neighbors4

Reports an agentset containing the 8 surrounding patches (neighbors) or 4 surrounding patches (neighbors4).

```
show sum [count turtles−here] of neighbors
  ;; prints the total number of turtles on the eight
  ;; patches around the calling turtle or patch
show count turtles−on neighbors
  ;; a shorter way to say the same thing
ask neighbors4 [ set pcolor red ]
  ;; turns the four neighboring patches red
```

<breed>−neighbors
link−neighbors

<breed>−neighbors
link−neighbors

Reports the agentset of all turtles found at the other end of undirected links connected to the calling turtle.

```
crt 3
```

```
ask turtle 0
[
  create-links-with other turtles
  ask link-neighbors [ set color red ] ;; turtles 1 and 2 turn red
]
ask turtle 1
[
  ask link-neighbors [ set color blue ] ;; turtle 0 turns blue
]
end
```

<breed>-neighbor?
link-neighbor?

<breed>-neighbor? ***turtle***
link-neighbor? ***turtle***

Reports true if there is an undirected link between *turtle* and the caller.

```
crt 2
ask turtle 0
[
  create-link-with turtle 1
  show link-neighbor? turtle 1  ;; prints true
]
ask turtle 1
[
  show link-neighbor? turtle 0     ;; prints true
]
```

netlogo-applet?

netlogo-applet?

Reports true if the model is running as an applet.

netlogo-version

netlogo-version

Reports a string containing the version number of the NetLogo you are running.

```
show netlogo-version
=> "4.0"
```

new-seed

new-seed

Reports a number suitable for seeding the random number generator.

The numbers reported by new−seed are based on the current date and time in milliseconds and lie in NetLogo's allowed range of integers, −9007199254740992 to 9007199254740992.

new−seed never reports the same number twice in succession. (This is accomplished by waiting a millisecond if the seed for the current millisecond was already used.)

See also random−seed.

no−display

no−display

Turns off all updates to the current view until the display command is issued. This has two major uses.

One, you can control when the user sees view updates. You might want to change lots of things on the view behind the user's back, so to speak, then make them visible to the user all at once.

Two, your model will run faster when view updating is off, so if you're in a hurry, this command will let you get results faster. (Note that normally you don't need to use no−display for this, since you can also use the on/off switch in view control strip to freeze the view.)

Note that display and no−display operate independently of the switch in the view control strip that freezes the view.

See also display.

nobody

nobody

This is a special value which some primitives such as turtle, one−of, max−one−of, etc. report to indicate that no agent was found. Also, when a turtle dies, it becomes equal to nobody.

Note: Empty agentsets are not equal to nobody. If you want to test for an empty agentset, use any?. You only get nobody back in situations where you were expecting a single agent, not a whole agentset.

```
set other one-of other turtles-here
if other != nobody
  [ ask other [ set color red ] ]
```

no−links

no−links

Reports an empty link agentset.

no−patches

no−patches

Reports an empty patch agentset.

---

not

not *boolean*

Reports true if *boolean* is false, otherwise reports false.

```
if not any? turtles [ crt 10 ]
```

---

no−turtles

no−turtles

Reports an empty turtles agentset.

O

---

of

[*reporter*] of *agent*
[*reporter*] of *agentset*

For an agent, reports the value of the reporter for that agent (turtle or patch).

```
show [pxcor] of patch 3 5
;; prints 3
show [pxcor] of one−of patches
;; prints the value of a random patch's pxcor variable
show [who * who] of turtle 5
=> 25
show [count turtles in−radius 3] of patch 0 0
;; prints the number of turtles located within a
;; three−patch radius of the origin
```

For an agentset, reports a list that contains the value of the reporter for each agent in the agentset (in random order).

```
crt 4
show sort [who] of turtles
=> [0 1 2 3]
show sort [who * who] of turtles
=> [0 1 4 9]
```

---

one−of

one−of *agentset*
one−of *list*

From an agentset, reports a random agent. If the agentset is empty, reports nobody.

From a list, reports a random list item. It is an error for the list to be empty.

```
ask one-of patches [ set pcolor green ]
;; a random patch turns green
ask patches with [any? turtles-here]
  [ show one-of turtles-here ]
;; for each patch containing turtles, prints one of
;; those turtles

;; suppose mylist is [1 2 3 4 5 6]
show one-of mylist
;; prints a value randomly chosen from the list
```

See also n−of.

---

or

boolean1* or *boolean2

Reports true if either *boolean1* or *boolean2*, or both, is true.

Note that if *condition1* is true, then *condition2* will not be run (since it can't affect the result).

```
if (pxcor > 0) or (pycor > 0) [ set pcolor red ]
;; patches turn red except in lower-left quadrant
```

---

other

other *agentset*

Reports an agentset which is the same as the input agentset but omits the calling agent.

```
show count turtles-here
=> 10
show count other turtles-here
=> 9
```

---

other−end

other−end

If run by a turtle, reports the turtle at the other end of the asking link.

If run by a link, reports the turtle at the end of the link that isn't the asking turtle.

These definitions are difficult to understand in the abstract, but the following examples should help:

```
ask turtle 0 [ create-link-with turtle 1 ]
ask turtle 0 [ ask link 0 1 [ show other-end ] ] ;; prints turtle 1
ask turtle 1 [ ask link 0 1 [ show other-end ] ] ;; prints turtle 0
ask link 0 1 [ ask turtle 0 [ show other-end ] ] ;; prints turtle 1
```

As these examples hopefully make plain, the "other" end is the end that is neither asking nor being asked.

---

out-<breed>-neighbor?
out-link-neighbor?

out-<breed>-neighbor? *turtle*
out-link-neighbor? *turtle*

Reports true if there is a directed link going from the caller to *turtle*.

```
crt 2
ask turtle 0 [
  create-link-to turtle 1
  show in-link-neighbor? turtle 1  ;; prints false
  show out-link-neighbor? turtle 1 ;; prints true
]
ask turtle 1 [
  show in-link-neighbor? turtle 0  ;; prints true
  show out-link-neighbor? turtle 0 ;; prints false
]
```

---

out-<breed>-neighbors
out-link-neighbors

out-<breed>-neighbors
out-link-neighbors

Reports the agentset of all the turtles that have directed links from the caller.

```
crt 4
ask turtle 0
[
  create-links-to other turtles
  ask out-link-neighbors [ set color pink ] ;; turtles 1-3 turn pink
]
ask turtle 1
[
  ask out-link-neighbors [ set color orange ]  ;; no turtles change colors
                                               ;; since turtle 1 only has in-links
]
end
```

---

out−<breed>−to
out−link−to

out−<breed>−to *turtle*
out−link−to *turtle*

Reports the link from the caller to *turtle*. If no link exists then it reports nobody.

```
crt 2
ask turtle 0 [
  create−link−to turtle 1
  show out−link−to turtle 1 ;; shows link 0 1
]
ask turtle 1
[
  show out−link−to turtle 0 ;; shows nobody
]
```

---

output−print
output−show
output−type
output−write

output−print *value*
output−show *value*
output−type *value*
output−write *value*

These commands are the same as the print, show, type, and write commands except that *value* is printed in the model's output area, instead of in the Command Center. (If the model does not have a separate output area, then the Command Center is used.)

P

---

patch

patch *xcor ycor*

Given the x and y coordinates of a point, reports the patch containing that point. (The coordinates are absolute coordinates; they are not computed relative to the calling agent, as with patch−at.)

If x and y are integers, the point is the center of a patch. If x or y is not an integer, rounding to the nearest integer is used to determine which patch contains the point.

If wrapping is allowed by the topology, the given coordinates will be wrapped to be within the world. If wrapping is not allowed and the given coordinates are outside the world, reports nobody.

```
ask patch 3 −4 [ set pcolor green ]
;; patch with pxcor of 3 and pycor of −4 turns green
```

```
show patch 1.2 3.7
;; prints (patch 1 4); note rounding
show patch 18 19
;; supposing min-pxcor and min-pycor are -17
;; and max-pxcor and max-pycor are 17,
;; in a wrapping topology, prints (patch -17 -16);
;; in a non-wrapping topology, prints nobody
```

See also patch-at.

patch-ahead

patch-ahead *distance*

Reports the single patch that is the given distance "ahead" of the calling turtle, that is, along the turtle's current heading. Reports nobody if the patch does not exist because it is outside the world.

```
ask patch-ahead 1 [ set pcolor green ]
;; turns the patch 1 in front of the calling turtle
;;   green; note that this might be the same patch
;;   the turtle is standing on
```

See also patch-at, patch-left-and-ahead, patch-right-and-ahead, patch-at-heading-and-distance.

patch-at

patch-at *dx dy*

Reports the patch at (dx, dy) from the caller, that is, the patch containing the point dx east and dy patches north of the calling agent.

Reports nobody if there is no such patch because that point is beyond a non-wrapping world boundary.

```
ask patch-at 1 -1 [ set pcolor green ]
;; if caller is a turtle or patch, turns the
;;   patch just southeast of the caller green
```

See also patch, patch-ahead, patch-left-and-ahead, patch-right-and-ahead, patch-at-heading-and-distance.

patch-at-heading-and-distance

patch-at-heading-and-distance *heading distance*

patch-at-heading-and-distance reports the single patch that is the given distance from the calling turtle or patch, along the given absolute heading. (In contrast to patch-left-and-ahead and patch-right-and-ahead, the calling turtle's current heading is not taken into account.) Reports

nobody if the patch does not exist because it is outside the world.

```
ask patch-at-heading-and-distance -90 1 [ set pcolor green ]
;; turns the patch 1 to the west of the calling patch
;;   green
```

See also patch, patch-at, patch-left-and-ahead, patch-right-and-ahead.

patch-here

patch-here

patch-here reports the patch under the turtle.

Note that this reporter isn't available to a patch because a patch can just say "self".

patch-left-and-ahead
patch-right-and-ahead

patch-left-and-ahead *angle distance*
patch-right-and-ahead *angle distance*

Reports the single patch that is the given distance from the calling turtle, in the direction turned left or right the given angle (in degrees) from the turtle's current heading. Reports nobody if the patch does not exist because it is outside the world.

(If you want to find a patch in a given absolute heading, rather than one relative to the current turtle's heading, use patch-at-heading-and-distance instead.)

```
ask patch-right-and-ahead 30 1 [ set pcolor green ]
;; the calling turtle "looks" 30 degrees right of its
;;   current heading at the patch 1 unit away, and turns
;;   that patch green; note that this might be the same
;;   patch the turtle is standing on
```

See also patch, patch-at, patch-at-heading-and-distance.

patch-set

patch-set *value1*
(patch-set *value1 value2* ...)

Reports an agentset containing all of the patches anywhere in any of the inputs. The inputs may be individual patches, patch agentsets, nobody, or lists (or nested lists) containing any of the above.

```
patch-set self
patch-set patch-here
(patch-set self neighbors)
(patch-set patch-here neighbors)
(patch-set patch 0 0 patch 1 3 patch 4 -2)
```

```
(patch-set patch-at -1 1 patch-at 0 1 patch-at 1 1)
patch-set [patch-here] of turtles
patch-set [neighbors] of turtles
```

See also turtle-set, link-set.

---

patches

patches

Reports the agentset consisting of all patches.

---

patches-own

patches-own [*var1* ...]

This keyword, like the globals, breed, <*breed*>-own, and turtles-own keywords, can only be used at the beginning of a program, before any function definitions. It defines the variables that all patches can use.

All patches will then have the given variables and be able to use them.

All patch variables can also be directly accessed by any turtle standing on the patch.

See also globals, turtles-own, breed, <*breeds*>-own.

---

pcolor

pcolor

This is a built-in patch variable. It holds the color of the patch. You can set this variable to make the patch change color.

All patch variables can be directly accessed by any turtle standing on the patch.

See also color.

---

pen-down
pd
pen-erase
pe
pen-up
pu

pen−down
pen−erase
pen−up

The turtle changes modes between drawing lines, removing lines or neither. The lines will always be displayed on top of the patches and below the turtles. To change the color of the pen set the color of the turtle using `set color`.

Note: When a turtle's pen is down, all movement commands cause lines to be drawn, including jump, setxy, and move−to.

Note: These commands are equivalent to setting the turtle variable "pen−mode" to "down" , "up", and "erase".

Note: On Windows drawing and erasing a line might not erase every pixel.

---

pen−mode

This is a built−in turtle variable. It holds the state of the turtle's pen. You set the variable to draw lines, erase lines or stop either of these actions. Possible values are "up", "down", and "erase".

---

pen−size

This is a built−in turtle variable. It holds the width of the line, in pixels, that the turtle will draw (or erase) when the pen is down (or erasing).

---

plabel

plabel

This is a built−in patch variable. It may hold a value of any type. The patch appears in the view with the given value "attached" to it as text. You can set this variable to add, change, or remove a patch's label.

All patch variables can be directly accessed by any turtle standing on the patch.

See also plabel−color, label, label−color.

---

plabel−color

plabel−color

This is a built−in patch variable. It holds a number greater than or equal to 0 and less than 140. This number determines what color the patch's label appears in (if it has a label). You can set this variable to change the color of a patch's label.

All patch variables can be directly accessed by any turtle standing on the patch.

See also plabel, label, label−color.

---

plot

plot *number*

Increments the x−value of the plot pen by plot−pen−interval, then plots a point at the updated x−value and a y−value of *number*. (The first time the command is used on a plot, the point plotted has an x−value of 0.)

---

plot−name

plot−name

Reports the name of the current plot (a string)

---

plot−pen−exists?

plot−pen−exists? *string*

Reports true if a plot pen with the given name is defined in the current plot. Otherwise reports false.

---

plot−pen−down
plot−pen−up

plot−pen−down
plot−pen−up

Puts down (or up) the current plot−pen, so that it draws (or doesn't). (By default, all pens are down initially.)

---

plot−pen−reset

plot−pen−reset

Clears everything the current plot pen has drawn, moves it to (0,0), and puts it down. If the pen is a permanent pen, the color and mode are reset to the default values from the plot Edit dialog.

---

plotxy

plotxy *number1 number2*

Moves the current plot pen to the point with coordinates (*number1*, *number2*). If the pen is down, a line, bar, or point will be drawn (depending on the pen's mode).

---

plot−x−min
plot−x−max
plot−y−min
plot−y−max

plot−x−min
plot−x−max
plot−y−min
plot−y−max

Reports the minimum or maximum value on the x or y axis of the current plot.

These values can be set with the commands set−plot−x−range and set−plot−y−range. (Their default values are set from the plot Edit dialog.)

---

position

position *item list*
position *string1 string2*

On a list, reports the first position of *item* in *list*, or false if it does not appear.

On strings, reports the position of the first appearance *string1* as a substring of *string2*, or false if it does not appear.

Note: The positions are numbered beginning with 0, not with 1.

```
;; suppose mylist is [2 7 4 7 "Bob"]
show position 7 mylist
=> 1
show position 10 mylist
=> false
show position "in" "string"
=> 3
```

See also member?.

---

precision

precision *number places*

Reports *number* rounded to *places* decimal places.

If *places* is negative, the rounding takes place to the left of the decimal point.

```
show precision 1.23456789 3
=> 1.235
show precision 3834 -3
=> 4000
```

---

print

print *value*

Prints *value* in the Command Center, followed by a carriage return.

The calling agent is *not* printed before the value, unlike show.

See also show, type, and write.

See also output-print.

---

pxcor
pycor

pxcor
pycor

These are built-in patch variables. They hold the x and y coordinate of the patch. They are always integers. You cannot set these variables, because patches don't move.

pxcor is greater than or equal to min-pxcor and less than or equal to max-pxcor; similarly for pycor and min-pycor and max-pycor.

All patch variables can be directly accessed by any turtle standing on the patch.

See also xcor, ycor.

R

---

random

random *number*

If *number* is positive, reports a random integer greater than or equal to 0, but strictly less than *number*.

If *number* is negative, reports a random integer less than or equal to 0, but strictly greater than *number*.

If *number* is zero, the result is always 0 as well.

Note: In versions of NetLogo prior to version 2.0, this primitive reported a floating point number if given a non−integer input. This is no longer the case. If you want a floating point answer, you must now use random−float instead.

```
show random 3
;; prints 0, 1,  or 2
show random −3
;; prints 0, −1, or −2
show random 3.5
;; prints 0, 1, 2, or 3
```

See also random−float.

---

random−float

random−float *number*

If *number* is positive, reports a random floating point number greater than or equal to 0 but strictly less than *number*.

If *number* is negative, reports a random floating point number less than or equal to 0, but strictly greater than *number*.

If *number* is zero, the result is always 0.

```
show random−float 3
;; prints a number at least 0 but less than 3,
;; for example 2.589444906014774
show random−float 2.5
;; prints a number at least 0 but less than 2.5,
;; for example 1.0897423196760796
```

---

random−exponential
random−gamma
random−normal
random−poisson

random−exponential *mean*
random−gamma *alpha lambda*
random−normal *mean standard−deviation*
random−poisson *mean*

Reports an accordingly distributed random number with the *mean* and, in the case of the normal distribution, the *standard−deviation*.

random−exponential reports an exponentially distributed random floating point number.

random−gamma reports a gamma−distributed random floating point number as controlled by the floating point alpha and lambda parameters. Both inputs must be greater than zero. (Note: for results with a given mean and variance, use inputs as follows: alpha = mean * mean / variance; lambda = 1 / (variance / mean).)

random−normal reports a normally distributed random floating point number.

random−poisson reports a Poisson−distributed random integer.

```
show random−exponential 2
;; prints an exponentially distributed random floating
;; point number with a mean of 2
show random−normal 10.1 5.2
;; prints a normally distributed random floating point
;; number with a mean of 10.1 and a standard deviation
;; of 5.2
show random−poisson 3.4
;; prints a Poisson−distributed random integer with a
;; mean of 3.4
```

---

random−pxcor
random−pycor

random−pxcor
random−pycor

Reports a random integer ranging from min−pxcor (or −y) to max−pxcor (or −y) inclusive.

```
ask turtles [
  ;; move each turtle to the center of a random patch
  setxy random−pxcor random−pycor
]
```

See also random−xcor, random−ycor.

---

random−seed

random−seed *number*

Sets the seed of the pseudo−random number generator to the integer part of *number*. The seed may be any integer in the range supported by NetLogo (−9007199254740992 to 9007199254740992).

See the Random Numbers section of the Programming Guide for more details.

```
random−seed 47823
show random 100
=> 57
show random 100
=> 91
random−seed 47823
show random 100
=> 57
show random 100
=> 91
```

---

random−xcor
random−ycor

random−xcor
random−ycor

Reports a random floating point number from the allowable range of turtle coordinates along the given axis, x or y.

Turtle coordinates range from min−pxcor − 0.5 (inclusive) to max−pxcor + 0.5 (exclusive) horizontally; vertically, substitute −y for −x.

```
ask turtles [
  ;; move each turtle to a random point
  setxy random−xcor random−ycor
]
```

See also random−pxcor, random−pycor.

---

read−from−string

read−from−string *string*

Interprets the given string as if it had been typed in the Command Center, and reports the resulting value. The result may be a number, list, string, or boolean value, or the special value "nobody".

Useful in conjunction with the user−input primitive for converting the user's input into usable form.

```
show read−from−string "3" + read−from−string "5"
=> 8
show length read−from−string "[1 2 3]"
=> 3
crt read−from−string user−input "Make how many turtles?"
;; the number of turtles input by the user
;; are created
```

---

reduce

reduce [*reporter*] *list*

Reduces a list from left to right using *reporter*, resulting in a single value. This means, for example, that `reduce [?1 + ?2] [1 2 3 4]` is equivalent to *(((1 + 2) + 3) + 4)*. If *list* has a single item, that item is reported. It is an error to reduce an empty list.

In *reporter*, use `?1` and `?2` to refer to the two objects being combined.

Since it can be difficult to develop an intuition about what `reduce` does, here are some simple examples which, while not useful in themselves, may give you a better understanding of this primitive:

```
show reduce [?1 + ?2] [1 2 3]
=> 6
```

```
show reduce [?1 - ?2] [1 2 3]
=> -4
show reduce [?2 - ?1] [1 2 3]
=> 2
show reduce [?1] [1 2 3]
=> 1
show reduce [?2] [1 2 3]
=> 3
show reduce [sentence ?1 ?2] [[1 2] [3 [4]] 5]
=> [1 2 3 [4] 5]
show reduce [fput ?2 ?1] (fput [] [1 2 3 4 5])
=> [5 4 3 2 1]
```

Here are some more useful examples:

```
;; find the longest string in a list
to-report longest-string [strings]
  report reduce
    [ifelse-value (length ?1 >= length ?2) [?1] [?2]]
    strings
end

show longest-string ["hi" "there" "!"]
=> "there"

;; count the number of occurrences of an item in a list
to-report occurrences [x the-list]
  report reduce
    [ifelse-value (?2 = x) [?1 + 1] [?1]] (fput 0 the-list)
end

show occurrences 1 [1 2 1 3 1 2 3 1 1 4 5 1]
=> 6

;; evaluate the polynomial, with given coefficients, at x
to-report evaluate-polynomial [coefficients x]
  report reduce [(x * ?1) + ?2] coefficients
end

;; evaluate 3x^2 + 2x + 1 at x = 4
show evaluate-polynomial [3 2 1] 4
=> 57
```

---

remainder

remainder *number1 number2*

Reports the remainder when *number1* is divided by *number2*. This is equivalent to the following NetLogo code:

```
number1 - (int (number1 / number2)) * number2
```

```
show remainder 62 5
=> 2
show remainder -8 3
=> -2
```

See also mod. mod and remainder behave the same for positive numbers, but differently for

negative numbers.

remove

remove *item list*
remove *string1 string2*

For a list, reports a copy of *list* with all instances of *item* removed.

For strings, reports a copy of *string2* with all the appearances of *string1* as a substring removed.

```
set mylist [2 7 4 7 "Bob"]
set mylist remove 7 mylist
;; mylist is now [2 4 "Bob"]
show remove "to" "phototonic"
=> "phonic"
```

remove−duplicates

remove−duplicates *list*

Reports a copy of *list* with all duplicate items removed. The first of each item remains in place.

```
set mylist [2 7 4 7 "Bob" 7]
set mylist remove−duplicates mylist
;; mylist is now [2 7 4 "Bob"]
```

remove−item

remove−item *index list*
remove−item *index string*

For a list, reports a copy of *list* with the item at the given index removed.

For strings, reports a copy of *string2* with the character at the given index removed.

Note that the indices begin from 0, not 1. (The first item is item 0, the second item is item 1, and so on.)

```
set mylist [2 7 4 7 "Bob"]
set mylist remove−item 2 mylist
;; mylist is now [2 7 7 "Bob"]
show remove−item 2 "string"
=> "sting"
```

repeat

repeat *number* [*commands*]

Runs *commands number* times.

```
pd repeat 36 [ fd 1 rt 10 ]
;; the turtle draws a circle
```

replace−item

replace−item *index list value*
replace−item *index string1 string2*

On a list, replaces an item in that list. *index* is the index of the item to be replaced, starting with 0. (The 6th item in a list would have an index of 5.) Note that "replace−item" is used in conjunction with "set" to change a list.

Likewise for a string, but the given character of *string1* removed and the contents of *string2* spliced in instead.

```
show replace−item 2 [2 7 4 5] 15
=> [2 7 15 5]
show replace−item 1 "cat" "are"
=> "caret"
```

report

report *value*

Immediately exits from the current to−report procedure and reports *value* as the result of that procedure. report and to−report are always used in conjunction with each other. See to−report for a discussion of how to use them.

reset−perspective
rp

reset−perspective

The observer stops watching, following, or riding any turtles (or patches). (If it wasn't watching, following, or riding anybody, nothing happens.) In the 3D view, the observer also returns to its default position (above the origin, looking straight down).

See also follow, ride, watch.

reset−ticks

reset−ticks

Resets the tick counter to zero.

See also tick, ticks, tick−advance.

reset−timer

reset−timer

Resets the timer to zero seconds. See also timer.

Note that the timer is different from the tick counter. The timer measures elapsed real time in seconds; the tick counter measures elapsed model time in ticks.

---

reverse

reverse *list*
reverse *string*

Reports a reversed copy of the given list or string.

```
show mylist
;; mylist is [2 7 4 "Bob"]
set mylist reverse mylist
;; mylist now is ["Bob" 4 7 2]
show reverse "live"
=> "evil"
```

---

rgb

rgb *red green blue*

Reports a RGB list when three numbers describing an RGB color. The numbers are range checked to be between 0 and 255.

See also hsb

---

ride

ride *turtle*

Set the perspective to *turtle*.

Every time *turtle* moves the observer also moves. Thus, in the 2D View the turtle will stay at the center of the view. In the 3D view it is as if looking through the eyes of the turtle. If the turtle dies, the perspective resets to the default.

See also reset−perspective, watch, follow, subject.

---

ride−me

ride−me

Asks the observer to ride the calling turtle.

See also ride.

---

right
rt

right *number*

The turtle turns right by *number* degrees. (If *number* is negative, it turns left.)

---

round

round *number*

Reports the integer nearest to *number*.

If the decimal portion of *number* is exactly .5, the number is rounded in the **positive** direction.

Note that rounding in the positive direction is not always how rounding is done in other software programs. (In particular, it does not match the behavior of StarLogoT, which always rounded numbers ending in 0.5 to the nearest even integer.) The rationale for this behavior is that it matches how turtle coordinates relate to patch coordinates in NetLogo. For example, if a turtle's xcor is −4.5, then it is on the boundary between a patch whose pxcor is −4 and a patch whose pxcor is −5, but the turtle must be considered to be in one patch or the other, so the turtle is considered to be in the patch whose pxcor is −4, because we round towards the positive numbers.

```
show round 4.2
=> 4
show round 4.5
=> 5
show round −4.5
=> −4
```

---

run

run *string*

This agent interprets the given string as a sequence of one or more NetLogo commands and runs them.

The code runs in the agent's current context, which means it has access to the values of local variables, "myself", and so on.

The code must be compiled first which takes time, however, compiled bits of code are cached by NetLogo and thus using `run` on the same string over and over is much faster than running on

different bits of code.

See also runresult.

Note that you can't use `run` to define or redefine procedures.

Note that running code through `run` or `runresult` may be many times slower than running the same code directly.

runresult

runresult *string*

This agent interprets the given string as a NetLogo reporter and runs it, reporting the result obtained.

The code runs in the agent's current context, which means it has access to the values of local variables, "myself", and so on.

The code must be compiled first which takes time, however, compiled bits of code are cached by NetLogo and thus using `runresult` on the same string over and over is much faster than running on different bits of code.

See also run.

Note that running code through `run` or `runresult` may be many times slower than running the same code directly.

S

scale−color

scale−color *color number range1 range2*

Reports a shade of *color* proportional to *number*.

If *range1* is less than *range2*, then the larger the number, the lighter the shade of *color*. But if *range2* is less than *range1*, the color scaling is inverted.

If *number* is less than *range1*, then the darkest shade of *color* is chosen.

If *number* is greater than *range2*, then the lightest shade of *color* is chosen.

Note: for *color* shade is irrelevant, e.g. green and green + 2 are equivalent, and the same spectrum of colors will be used.

```
ask turtles [ set color scale−color red age 0 50 ]
;; colors each turtle a shade of red proportional
;; to its value for the age variable
```

self

self

Reports this turtle or patch.

"self" and "myself" are very different. "self" is simple; it means "me". "myself" means "the turtle or patch who asked me to do what I'm doing right now."

See also myself.

; (semicolon)

; *comments*

After a semicolon, the rest of the line is ignored. This is useful for adding "comments" to your code −− text that explains the code to human readers. Extra semicolons can be added for visual effect.

NetLogo's Edit menu has items that let you comment or uncomment whole sections of code.

---

sentence
se

sentence *value1 value2*
(sentence *value1* ...)

Makes a list out of the values. If any value is a list, its items are included in the result directly, rather than being included as a sublist. Examples make this clearer:

```
show sentence 1 2
=> [1 2]
show sentence [1 2] 3
=> [1 2 3]
show sentence 1 [2 3]
=> [1 2 3]
show sentence [1 2] [3 4]
=> [1 2 3 4]
show sentence [[1 2]] [[3 4]]
=> [[1 2] [3 4]]
show (sentence [1 2] 3 [4 5] (3 + 3) 7)
=> [1 2 3 4 5 6 7]
```

---

set

set *variable value*

Sets *variable* to the given value.

Variable can be any of the following:

- A global variable declared using "globals"
- The global variable associated with a slider, switch, chooser, or input box.
- A variable belonging to the calling agent
- If the calling agent is a turtle, a variable belonging to the patch under the turtle.
- A local variable created by the let command.
- An input to the current procedure.
- A special local variable (?, ?1, ?2...).

---

set−current−directory

set−current−directory *string*

Sets the current directory that is used by the primitives file−delete, file−exists?, and file−open.

The current directory is not used if the above commands are given an absolute file path. This is defaulted to the user's home directory for new models, and is changed to the model's directory when a model is opened.

Note that in Windows file paths the backslash needs to be escaped within a string by using another backslash "C:\\"

The change is temporary and is not saved with the model.

Note: in applets, this command has no effect, since applets are only allowed to read files from the same directory on the server where the model is stored.

```
set−current−directory "C:\\NetLogo"
;; Assume it is a Windows Machine
file−open "my−file.txt"
;; Opens file "C:\\NetLogo\\my−file.txt"
```

---

set−current−plot

set−current−plot *plotname*

Sets the current plot to the plot with the given name (a string). Subsequent plotting commands will affect the current plot.

---

set−current−plot−pen

set−current−plot−pen *penname*

The current plot's current pen is set to the pen named *penname* (a string). If no such pen exists in the current plot, a runtime error occurs.

---

set−default−shape

set−default−shape turtles *string*
set−default−shape *breed string*

Specifies a default initial shape for all turtles, or for a particular breed. When a turtle is created, or it changes breeds, it shape is set to the given shape.

This command doesn't affect existing turtles, only turtles you create afterwards.

The specified breed must be either turtles or a breed defined by the breed keyword, and the specified string must be the name of a currently defined shape.

In new models, the default shape for all turtles is "default".

Note that specifying a default shape does not prevent you from changing an individual turtle's shape later; turtles don't have to be stuck with their breed's default shape.

```
create−turtles 1 ;; new turtle's shape is "default"
create−cats 1    ;; new turtle's shape is "default"

set−default−shape turtles "circle"
create−turtles 1 ;; new turtle's shape is "circle"
create−cats 1    ;; new turtle's shape is "circle"

set−default−shape cats "cat"
set−default−shape dogs "dog"
create−cats 1   ;; new turtle's shape is "cat"
ask cats [ set breed dogs ]
  ;; all cats become dogs, and automatically
  ;; change their shape to "dog"
```

See also shape.

---

set−histogram−num−bars

set−histogram−num−bars *number*

Set the current plot pen's plot interval so that, given the current x range for the plot, there would be *number* number of bars drawn if the histogram command is called.

See also histogram.

__set−line−thickness

__set−line−thickness *number*

Specifies the thickness of lines and outlined elements in the turtle's shape.

The default value is 0. This always produces lines one pixel thick.

Non−zero values are interpreted as thickness in patches. A thickness of 1, for example, produces

lines which appear one patch thick. (It's common to use a smaller value such as 0.5 or 0.2.)

Lines are always at least one pixel thick.

This command is experimental and may change in later releases.

---

set−plot−pen−color

set−plot−pen−color *number*

Sets the color of the current plot pen to *number*.

---

set−plot−pen−interval

set−plot−pen−interval *number*

Tells the current plot pen to move a distance of *number* in the x direction during each use of the plot command. (The plot pen interval also affects the behavior of the histogram command.)

---

set−plot−pen−mode

set−plot−pen−mode *number*

Sets the mode the current plot pen draws in to *number*. The allowed plot pen modes are:

- 0 (line mode) the plot pen draws a line connecting two points together.
- 1 (bar mode): the plot pen draws a bar of width plot−pen−interval with the point plotted as the upper (or lower, if you are plotting a negative number) left corner of the bar.
- 2 (point mode): the plot pen draws a point at the point plotted. Points are not connected.

The default mode for new pens is 0 (line mode).

---

set−plot−x−range
set−plot−y−range

set−plot−x−range *min max*
set−plot−y−range *min max*

Sets the minimum and maximum values of the x or y axis of the current plot.

The change is temporary and is not saved with the model. When the plot is cleared, the ranges will revert to their default values as set in the plot's Edit dialog.

---

setxy

setxy *x y*

The turtle sets its x−coordinate to *x* and its y−coordinate to *y*.

Equivalent to `set xcor x set ycor y`, except it happens in one time step instead of two.

If *x* or *y* is outside the world, NetLogo will throw a runtime error.

```
setxy 0 0
;; turtle moves to the middle of the center patch
setxy random−xcor random−ycor
;; turtle moves to a random point
setxy random−pxcor random−pycor
;; turtle moves to the center of a random patch
```

See also move−to.

---

shade−of?

shade−of? *color1 color2*

Reports true if both colors are shades of one another, false otherwise.

```
show shade−of? blue red
=> false
show shade−of? blue (blue + 1)
=> true
show shade−of? gray white
=> true
```

---

shape

shape

This is a built−in turtle and link variable. It holds a string that is the name of the turtle or link's current shape. You can set this variable to change the shape. New turtles and links have the shape "default" unless the a different shape has been specified using set−default−shape.

Example:

```
ask turtles [ set shape "wolf" ]
;; assumes you have made a "wolf"
;; shape in NetLogo's Turtle Shapes Editor
ask links [ set shape "link 1" ]
;; assumes you have made a "link 1" shape in
;; the Link Shapes Editor
```

See also set−default−shape, shapes.

---

shapes

shapes

Reports a list of strings containing all of the turtle shapes in the model.

New shapes can be created, or imported from the shapes library or from other models, in the Shapes Editor.

```
show shapes
=> ["default" "airplane" "arrow" "box" "bug" ...
ask turtles [ set shape one-of shapes ]
```

---

show

show *value*

Prints *value* in the Command Center, preceded by the calling agent, and followed by a carriage return. (The calling agent is included to help you keep track of what agents are producing which lines of output.) Also, all strings have their quotes included similar to write.

See also print, type, and write.

See also output-show.

---

show-turtle
st

show-turtle

The turtle becomes visible again.

Note: This command is equivalent to setting the turtle variable "hidden?" to false.

See also hide-turtle.

---

shuffle

shuffle *list*

Reports a new list containing the same items as the input list, but in randomized order.

```
show shuffle [1 2 3 4 5]
=> [5 2 4 1 3]
show shuffle [1 2 3 4 5]
=> [1 3 5 2 4]
```

---

sin

sin *number*

Reports the sine of the given angle. Assumes angle is given in degrees.

```
show sin 270
=> −1
```

---

size

size

This is a built−in turtle variable. It holds a number that is the turtle's apparent size. The default size is 1, which means that the turtle is the same size as a patch. You can set this variable to change a turtle's size.

---

sort

sort *list−of−numbers*
sort *list−of−strings*
sort *agentset*

If the input is a list of numbers or strings, reports a new list containing the same items as the input list, but in ascending order (numeric or alphabetic).

Any list items that are not numbers or strings are ignored. (If the input list contains no numbers or strings, the result is an empty list.)

If the input is an agentset or a list of agents, reports a list (never an agentset) of agents. If the agents are turtles, they are listed in ascending order by who number. If the agents are patches, they are listed left−to−right, top−to−bottom.

```
show sort [3 1 4 2]
=> [1 2 3 4]
let n 0
foreach sort patches [
  ask ? [
    set plabel n
    set n n + 1
  ]
]
;; patches are labeled with numbers in left−to−right,
;; top−to−bottom order
```

---

sort−by

sort−by [*reporter*] *list*
sort−by [*reporter*] *agentset*

If the input is a list, reports a new list containing the same items as the input list, in a sorted order defined by the boolean (true or false) *reporter*.

In *reporter*, use ?1 and ?2 to refer to the two objects being compared. *reporter* should be true if ?1 comes strictly before ?2 in the desired sort order, and false otherwise.

If the input is an agentset or a list of agents, reports a list (never an agentset) of agents.

The sort is stable, that is, the order of items considered equal by the reporter is not disturbed.

```
show sort-by [?1 < ?2] [3 1 4 2]
=> [1 2 3 4]
show sort-by [?1 > ?2] [3 1 4 2]
=> [4 3 2 1]
show sort-by [length ?1 < length ?2] ["Grumpy" "Doc" "Happy"]
=> ["Doc" "Happy" "Grumpy"]
foreach sort-by [[size] of ?1 < [size] of ?2] turtles
  [ ask ? [ do-something ] ]
;; turtles run "do-something" one at a time, in
;; ascending order by size
```

---

sprout
sprout-<*breeds*>

sprout *number* [*commands*]
sprout-<*breeds*> *number* [*commands*]

Creates *number* new turtles on the current patch. The new turtles have random colors and headings, and they immediately run *commands*. This is useful for giving the new turtles different colors, headings, or whatever. (The new turtles are created all at once then run one at a time, in random order.)

If the sprout-<*breeds*> form is used, the new turtles are created as members of the given breed.

```
sprout 5
sprout-wolves 10
sprout 1 [ set color red ]
sprout-sheep 1 [ set color black ]
```

Note: While the commands are running, no other agents are allowed to run any code (as with the without-interruption command). This ensures that if `ask-concurrent` is being used, the new turtles cannot interact with any other agents until they are fully initialized.

See also create-turtles, hatch.

---

sqrt

sqrt *number*

Reports the square root of *number*.

---

stamp

stamp

The calling turtle or link leaves an image of its shape in the drawing at its current location.

Note: The shapes made by stamp may not be pixel−for−pixel identical from computer to computer.

---

stamp−erase

stamp−erase

The calling turtle or link removes any pixels below it in the drawing inside the bounds of its shape.

Note: The shapes made by stamp−erase may not be pixel−for−pixel identical from computer to computer.

---

standard−deviation

standard−deviation *list*

Reports the unbiased statistical standard deviation of a *list* of numbers. Ignores other types of items.

```
show standard−deviation [1 2 3 4 5 6]
=> 1.8708286933869707
show standard−deviation [energy] of turtles
;; prints the standard deviation of the variable "energy"
;; from all the turtles
```

---

startup

startup

User−defined procedure which, if it exists, will be called when a model is first loaded.

```
to startup
  setup
end
```

---

stop

stop

The calling agent exits immediately from the enclosing procedure, ask, or ask−like construct (crt, hatch, sprout, without−interruption). Only the current procedure stops, not all execution for the agent.

```
if not any? turtles [ stop ]
```

```
;; exits if there are no more turtles
```

Note: stop can be used to stop a forever button. If the forever button directly calls a procedure, then when that procedure stops, the button stops. (In a turtle or patch forever button, the button won't stop until every turtle or patch stops −− a single turtle or patch doesn't have the power to stop the whole button.)

---

subject

subject

Reports the turtle (or patch) that the observer is currently watching, following, or riding. Reports nobody if there is no such turtle (or patch).

See also watch, follow, ride.

---

sublist
substring

sublist *list position1 position2*
substring *string position1 position2*

Reports just a section of the given list or string, ranging between the first position (inclusive) and the second position (exclusive).

Note: The positions are numbered beginning with 0, not with 1.

```
show sublist [99 88 77 66] 1 3
=> [88 77]
show substring "apartment" 1 5
=> "part"
```

---

subtract−headings

subtract−headings *heading1 heading2*

Computes the difference between the given headings, that is, the number of degrees in the smallest angle by which heading2 could be rotated to produce heading1. A positive answer means a clockwise rotation, a negative answer counterclockwise. The result is always in the range −180 to 180, but is never exactly −180.

Note that simply subtracting the two headings using the − (minus) operator wouldn't work. Just subtracting corresponds to always rotating clockwise from heading2 to heading1; but sometimes the counterclockwise rotation is shorter. For example, the difference between 5 degrees and 355 degrees is 10 degrees, not −350 degrees.

```
show subtract−headings 80 60
=> 20
show subtract−headings 60 80
=> −20
show subtract−headings 5 355
```

```
=> 10
show subtract-headings 355 5
=> -10
show subtract-headings 180 0
=> 180
show subtract-headings 0 180
=> 180
```

sum

sum *list*

Reports the sum of the items in the list.

```
show sum [energy] of turtles
;; prints the total of the variable "energy"
;; from all the turtles
```

T

tan

tan *number*

Reports the tangent of the given angle. Assumes the angle is given in degrees.

thickness

thickness

This is a built-in link variable. It holds a number that is the link's apparent size as a fraction of the patch size. The thickness is 0, which means that regardless of patch-size the links will always appear 1 pixel wide. You can set this variable to change a link's thickness.

tick

tick

Advances the tick counter by one.

See also ticks, tick-advance, reset-ticks.

tick-advance

tick-advance *number*

Advances the tick counter by *number*. The input may be an integer or a floating point number. (Some models divide ticks more finely than by ones.) The input may not be negative.

See also tick, ticks, reset−ticks.

ticks

ticks

Reports the current value of the tick counter. The result is always a number and never negative.

Most models use the `tick` command to advance the tick counter, in which case `ticks` will always report an integer. If the `tick−advance` command is used, then `ticks` may report a floating point number.

See also tick, tick−advance, reset−ticks.

tie

tie

Ties *end2* and *end2* of the link together. If the link is a directed link *end1* is the *root turtle* and *end2* is the *leaf turtle*. The movement of the *root turtle* affects the location and heading of the *leaf turtle*. If the link is undirected the tie is reciprocal so both turtles can be considered *root turtles* and *leaf turtles*. Movement or change in heading of either turtle affects the location and heading of the other turtle.

When the root turtle moves, the leaf turtles moves the same distance, in the same direction. The heading of the leaf turtle is not affected. This works with forward, jump, and setting the xcor or ycor of the root turtle.

When the root turtle turns right or left, the leaf turtle is rotated around the root turtle the same amount. The heading of the leaf turtle is also changed by the same amount.

If the link dies, the tie relation is removed.

```
crt 2 [ fd 3 ]
;; creates a link and ties turtle 1 to turtle 0
ask turtle 0 [ create−link−to turtle 1 [ tie ] ]
```

See also untie

tie−mode

tie−mode

This is a built−in link variable. It holds a string that is the name of the tie mode the link is currently in. Using the tie and untie commands changes the mode of the link. You can also set tie−mode to

"free" to create a non−rigid joint between two turtles (see the Tie section of the Programming Guide for details. By default links are not tied.

See also: tie, untie

---

timer

timer

Reports how many seconds have passed since the command reset−timer was last run (or since NetLogo started). The potential resolution of the clock is milliseconds. (Whether you get resolution that high in practice may vary from system to system, depending on the capabilities of the underlying Java Virtual Machine.)

See also reset−timer.

Note that the timer is different from the tick counter. The timer measures elapsed real time in seconds; the tick counter measures elapsed model time in ticks.

---

to

to *procedure−name*
to *procedure−name* [*input1* ...]

Used to begin a command procedure.

```
to setup
  clear-all
  crt 500
end

to circle [radius]
  crt 100 [ fd radius ]
end
```

---

to−report

to−report *procedure−name*
to−report *procedure−name* [*input1* ...]

Used to begin a reporter procedure.

The body of the procedure should use `report` to report a value for the procedure. See report.

```
to-report average [a b]
  report (a + b) / 2
end

to-report absolute-value [number]
  ifelse number >= 0
    [ report number ]
    [ report (- number) ]
end
```

```
to-report first-turtle?
  report who = 0  ;; reports true or false
end
```

towards

towards *agent*

Reports the heading from this agent to the given agent.

If wrapping is allowed by the topology and the wrapped distance (around the edges of the world) is shorter, towards will use the wrapped path.

Note: asking for the heading from an agent to itself, or an agent on the same location, will cause a runtime error.

```
set heading towards turtle 1
;; same as "face turtle 1"
```

See also face.

towardsxy

towardsxy *x y*

Reports the heading from the turtle or patch towards the point (*x*,*y*).

If wrapping is allowed by the topology and the wrapped distance (around the edges of the world) is shorter, towardsxy will use the wrapped path.

Note: asking for the heading to the point the agent is already standing on will cause a runtime error.

See also facexy.

turtle

turtle *number* <breed> *number*

Reports the turtle with the given who number, or nobody if there is no such turtle. For breeded turtles you may also use the single breed form to refer to them.

```
ask turtle 5 [ set color red ]
;; turtle with who number 5 turns red
```

turtle−set

turtle−set *value1*
(turtle−set *value1 value2* ...)

Reports an agentset containing all of the turtles anywhere in any of the inputs. The inputs may be individual turtles, turtle agentsets, nobody, or lists (or nested lists) containing any of the above.

```
turtle−set self
(turtle−set self turtles−on neighbors)
(turtle−set turtle 0 turtle 2 turtle 9)
(turtle−set frogs mice)
```

See also patch−set, link−set.

---

turtles

turtles

Reports the agentset consisting of all turtles.

```
show count turtles
;; prints the number of turtles
```

---

turtles−at
<breeds>−at

turtles−at *dx dy*
<breeds>*−at *dx dy

Reports an agentset containing the turtles on the patch (dx, dy) from the caller (including the caller itself if it's a turtle). If the caller is the observer, dx and dy are calculated from the origin (0,0).

```
;; suppose I have 40 turtles at the origin
show count turtles−at 0 0
=> 40
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

```
breed [cats cat]
breed [dogs dog]
create−dogs 5 [ setxy 2 3 ]
show count dogs−at 2 3
=> 5
```

---

turtles−here
<breed>−here

turtles−here
***<breeds>*−here**

Reports an agentset containing all the turtles on the caller's patch (including the caller itself if it's a turtle).

```
crt 10
ask turtle 0 [ show count turtles-here ]
=> 10
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

```
breed [cats cat]
breed [dogs dog]
create-cats 5
create-dogs 1
ask dogs [ show count cats-here ]
=> 5
```

---

turtles−on
<breeds>−on

turtles−on *agent*
turtles−on *agentset*
<breeds>*−on *agent
<breeds>*−on *agentset

Reports an agentset containing all the turtles that are on the given patch or patches, or standing on the same patch as the given turtle or turtles.

```
ask turtles [
  if not any? turtles-on patch-ahead 1
    [ fd 1 ]
]
ask turtles [
  if not any? turtles-on neighbors [
    die-of-loneliness
  ]
]
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

---

turtles−own
<breeds>−own

turtles−own [*var1* ...]
***<breeds>*−own [*var1* ...]**

The turtles−own keyword, like the globals, breed, *<breeds>*−own, and patches−own keywords, can only be used at the beginning of a program, before any function definitions. It defines the variables belonging to each turtle.

If you specify a breed instead of "turtles", only turtles of that breed have the listed variables. (More than one breed may list the same variable.)

```
breed [cats cat ]
breed [dogs dog]
breed [hamsters hamster]
turtles-own [eyes legs]   ;; applies to all breeds
cats-own [fur kittens]
hamsters-own [fur cage]
dogs-own [hair puppies]
```

See also globals, patches-own, breed, <*breeds*>-own.

---

type

type *value*

Prints *value* in the Command Center, *not* followed by a carriage return (unlike print and show). The lack of a carriage return allows you to print several values on the same line.

The calling agent is *not* printed before the value. unlike show.

```
type 3 type " " print 4
=> 3 4
```

See also print, show, and write.

See also output-type.

U

---

undirected-link-breed

undirected-link-breed [<*link-breeds*> <*link-breed*>]

This keyword, like the globals and breeds keywords, can only be used at the beginning of the Procedures tab, before any procedure definitions. It defines an undirected link breed. Links of a particular breed are always either all directed or all undirected. The first input defines the name of the agentset associated with the link breed. The second input defines the name of a single member of the breed.

Any link of the given link breed:

- is part of the agentset named by the link breed name
- has its built-in variable `breed` set to that agentset
- is directed or undirected as declared by the keyword

Most often, the agentset is used in conjunction with ask to give commands to only the links of a particular breed.

```
undirected-link-breed [streets street]
```

```
undirected-link-breed [highways highway]
to setup
  clear-all
  crt 2
  ask turtle 0 [ create-street-with turtle 1 ]
  ask turtle 0 [ create-highway-with turtle 1 ]
end

ask turtle 0 [ show sort my-links ]
;; prints [(street 0 1) (highway 0 1)]
```

See also breed, directed-link-breed

---

untie

untie

Unties *end2* from *end1* (sets tie-mode to "none") if they were previously tied together. If the link is an undirected link, then it will untie *end1* from *end2* as well. It does **not** remove the link between the two turtles.

See also tie

See the Tie section of the Programming Guide for more details.

---

uphill
uphill4

uphill *patch-variable*
uphill4 *patch-variable*

Moves the turtle to the neighboring patch with the highest value for *patch-variable*. If no neighboring patch has a higher value than the current patch, the turtle stays put. If there are multiple patches with the same highest value, the turtle picks one randomly. Non-numeric values are ignored.

uphill considers the eight neighboring patches; uphill4 only considers the four neighbors.

Equivalent to the following code (assumes variable values are numeric):

```
move-to patch-here  ;; go to patch center
let p max-one-of neighbors [patch-variable]  ;; or neighbors4
if [patch-variable] of p > patch-variable [
  face p
  move-to p
]
```

Note that the turtle always ends up on a patch center and has a heading that is a multiple of 45 (uphill) or 90 (uphill4).

See also uphill, uphill4.

user−directory

user−directory

Opens a dialog that allows the user to choose an existing directory on the system.

It reports a string with the absolute path or false if the user cancels.

```
set−current−directory user−directory
;; Assumes the user will choose a directory
```

user−file

user−file

Opens a dialog that allows the user to choose an existing file on the system.

It reports a string with the absolute file path or false if the user cancels.

```
file−open user−file
;; Assumes the user will choose a file
```

user−new−file

user−new−file

Opens a dialog that allows the user to choose a location and name of a new file to be created. It reports a string with the absolute file path or false if the user cancels.

```
file−open user−new−file
;; Assumes the user will choose a file
```

Note that this reporter doesn't actually create the file; normally you would create the file using `file−open`, as in the example.

If the user chooses an existing file, they will be asked if they wish to replace it or not, but the the reporter itself doesn't cause the file to be replaced. To do that you would use `file−delete`.

user−input

user−input *value*

Reports the string that a user types into an entry field in a dialog with title *value*.

value may be of any type, but is typically a string.

```
show user−input "What is your name?"
```

user−message

user−message *value*

Opens a dialog with *value* displayed as the message.

value may be of any type, but is typically a string.

```
user−message (word "There are " count turtles " turtles.")
```

user−one−of

user−one−of *value list−of−choices*

Opens a dialog with *value* displayed as the message and *list−of−choices* displayed as a popup menu for the user to select from.

Reports the item in *list−of−choices* selected by the user.

value may be of any type, but is typically a string.

```
if "yes" = user−one−of? "Set up the model?" ["yes" "no"]
  [ setup ]
```

user−yes−or−no?

user−yes−or−no? *value*

Reports true or false based on the user's response to *value*.

value may be of any type, but is typically a string.

```
if user−yes−or−no? "Set up the model?"
  [ setup ]
```

V

variance

variance *list*

Reports the sample variance of a *list* of numbers. Ignores other types of items.

The sample variance is the sum of the squares of the deviations of the numbers from their mean, divided by one less than the number of numbers in the list.

```
show variance [2 7 4 3 5]
=> 3.7
```

W

wait

wait *number*

Wait the given number of seconds. (This needn't be an integer; you can specify fractions of seconds.) Note that you can't expect complete precision; the agent will never wait less than the given amount, but might wait slightly more.

```
repeat 10 [ fd 1 wait 0.5 ]
```

See also every.

watch

watch *agent*

Puts a spotlight on *agent*. In the 3D view the observer will also turn to face the subject.

See also follow, subject, reset−perspective, watch−me.

watch−me

watch−me

Asks the observer to watch the calling agent.

See also watch.

while

while [*reporter*] [*commands*]

If *reporter* reports false, exit the loop. Otherwise run *commands* and repeat.

The reporter may have different values for different agents, so some agents may run *commands* a different number of times than other agents.

```
while [any? other turtles-here]
  [ fd 1 ]
;; turtle moves until it finds a patch that has
;; no other turtles on it
```

who

who

This is a built−in turtle variable. It holds the turtle's "who number" or ID number, an integer greater than or equal to zero. You cannot set this variable; a turtle's who number never changes.

Who numbers start at 0. A dead turtle's number will not be reassigned to a new turtle until you use the clear−turtles or clear−all commands, at which time who numbering starts over again at 0.

Example:

```
show [who] of turtles with [color = red]
;; prints a list of the who numbers of all red turtles
;; in the Command Center, in random order
crt 100
  [ ifelse who < 50
      [ set color red ]
      [ set color blue ] ]
;; turtles 0 through 49 are red, turtles 50
;; through 99 are blue
```

You can use the turtle reporter to retrieve a turtle with a given who number. See also turtle.

---

with

***agentset* with [*reporter*]**

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a boolean reporter. Reports a new agentset containing only those agents that reported true −− in other words, the agents satisfying the given condition.

```
show count patches with [pcolor = red]
;; prints the number of red patches
```

<breed>−with
link−with

<breed>−with *turtle*
link−with *turtle*

Report the link between *turtle* and the caller. If no link exists then it reports nobody.

```
crt 2
ask turtle 0 [
  create−link−with turtle 1
  show link−with turtle 1 ;; prints link 0 1
]
```

---

with−max

***agentset* with−max [*reporter*]**

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a reporter. Reports a new agentset containing all agents reporting the maximum value of the given reporter.

```
show count patches with−max [pxcor]
;; prints the number of patches on the right edge
```

See also max−one−of

---

with−min

***agentset* with−min [*reporter*]**

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a reporter. Reports a new agentset containing only those agents that have the minimum value of the given reporter.

```
show count patches with−min [pycor]
;; prints the number of patches on the bottom edge
```

See also min−one−of

---

with−local−randomness

with−local−randomness [*commands*]

The commands are run without affecting subsequent random events. This is useful for performing extra operations (such as output) without changing the outcome of a model.

Example:

```
;; Run #1:
random−seed 50 setup repeat 10 [ go ]
;; Run #2:
random−seed 50 setup
with−local−randomness [ watch one−of turtles ]
repeat 10 [ go ]
```

Since `one−of` is used inside `without−local−randomness`, both runs will be identical.

Specifically how it works is, the state of the random number generator is remembered before the commands run, then restored afterwards. (If you want to run the commands with a fresh random state instead of the same random state that will be restored later, you can begin the commands with `random−seed new−seed`.)

The following example demonstrates that the random number generator state is the same both before the commands run and afterwards.

```
random−seed 10
```

```
with-local-randomness [ print n-values 10 [random 10] ]
;; prints [8 9 8 4 2 4 5 4 7 9]
print n-values 10 [random 10]
;; prints [8 9 8 4 2 4 5 4 7 9]
```

without-interruption

without-interruption [*commands*]

The agent runs all the commands in the block without allowing other agents using `ask-concurrent` to "interrupt". That is, other agents are put "on hold" and do not run any commands until the commands in the block are finished.

Note: This command is only useful in conjunction with `ask-concurrent`. In previous versions of NetLogo, this command was often needed, but in NetLogo 4.0, it is only ever needed if you are also using `ask-concurrent`.

See also ask-concurrent.

word

word *value1 value2*
(word *value1* ...)

Concatenates the inputs together and reports the result as a string.

```
show word "tur" "tle"
=> "turtle"
word "a" 6
=> "a6"
set directory "c:\\foo\\fish\\"
show word directory "bar.txt"
=> "c:\foo\fish\bar.txt"
show word [1 54 8] "fishy"
=> "[1 54 8]fishy"
show (word 3)
=> "3"
show (word "a" "b" "c" 1 23)
=> "abc123"
```

world-width
world-height

world-width
world-height

These reporters give the total width and height of the NetLogo world.

The width equals max-pxcor - min-pxcor + 1 and the height equals max-pycor - min-pycor + 1.

See also max-pxcor, max-pycor, min-pxcor, and min-pycor

wrap−color

wrap−color *number*

wrap−color checks whether *number* is in the NetLogo color range of 0 to 140 (not including 140 itself). If it is not, wrap−color "wraps" the numeric input to the 0 to 140 range.

The wrapping is done by repeatedly adding or subtracting 140 from the given number until it is in the 0 to 140 range. (This is the same wrapping that is done automatically if you assign an out−of−range number to the color turtle variable or pcolor patch variable.)

```
show wrap-color 150
=> 10
show wrap-color -10
=> 130
```

---

write

write *value*

This command will output *value*, which can be a number, string, list, boolean, or nobody to the Command Center, *not* followed by a carriage return (unlike print and show).

The calling agent is *not* printed before the value, unlike show. Its output will also includes quotes around strings and is prepended with a space.

```
write "hello world"
=>  "hello world"
```

See also print, show, and type.

See also output−write.

X

---

xcor

xcor

This is a built−in turtle variable. It holds the current x coordinate of the turtle. You can set this variable to change the turtle's location.

This variable is always greater than or equal to (min−pxcor − 0.5) and strictly less than (max−pxcor + 0.5).

See also setxy, ycor, pxcor, pycor,

---

xor

boolean1* xor *boolean2

Reports true if either *boolean1* or *boolean2* is true, but not when both are true.

```
if (pxcor > 0) xor (pycor > 0)
  [ set pcolor blue ]
;; upper−left and lower−right quadrants turn blue
```

Y

ycor

ycor

This is a built−in turtle variable. It holds the current y coordinate of the turtle. You can set this variable to change the turtle's location.

This variable is always greater than or equal to (min−pycor − 0.5) and strictly less than (max−pycor + 0.5).

See also setxy, xcor, pxcor, pycor,

?

?, ?1, ?2, ?3, ...

?, ?1, ?2, ?3, ...

These are special local variables. They hold the current inputs to a reporter or command block for certain primitives (for example, the current item of a list being visited by foreach or map).

? is always equivalent to ?1.

You may not set these variables, and you may not use them except with certain primitives, currently foreach, map, reduce, filter, sort−by, and n−values. See those entries for example usage.